AN ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS IN ALBERTA

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Prepared By:

J.M Mulligan and Associates Ltd.

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Appendix A - Hardy and Associates (1978) Ltd.

Appendix B - Survey Analysis

1.0 Introduction

In late 1983 concerns were raised by the Manufactured Housing Association of Alberta (MHAA) that the Canadian Standards Association (CSA) Subcomittee on Mobile Homes was considering the establishment of new, more rigorous foundation standards. Their key concern was that the standards would result in high cost foundations which, in turn, would have a significant impact on the overall price of a manufactured housing unit and adversely affect its affordability. The MHAA felt that there was insufficient evidence of failure of commonly used surface mounted wood block systems to warrant the imposition of costly new standards. As a result, the Alberta Department of Housing agreed to commission this study to collect empirical information on the performance of mobile home foundations, particularly wood block foundations, and establish criteria for the design of appropriate foundations.

1.1 Purpose

The primary purpose of this study was to provide information on the characteristics and performance of dominant foundation systems.

1.2 Objectives

The specific objectives of the study are as follows:

a) To assess the performance of traditional manufactured housing wood block foundations in representative frost susceptible soils in different climatic areas in Alberta.

b) To assess the effect of frost penetration under manufactured housing which had been installed with non-insulated skirting.

c) To recommend limits of tolerable movements in foundations for manufactured homes.

d) To quantify the costs of the traditional surface wood blocking foundation system.

e) To estimate the costs of a range of subsurface foundations which have been developed for C.M.H.C.

1.3 Limitations.

In the assessment of foundation movement, it is not the intent of this report to study or make recommendations with respect to wind, flood or other inclement weather effects or provide guidelines to satisfy or predict the action of founding soils, or suggest anchoring systems to provide safety margins against sliding or overturning.

1.4 Approach

The study was planned to be executed in three phases as follows:

1.4.1 Phase One

Phase one provides a review of foundation characteristics, with emphasis on typical foundation types used in the mobile home industry, each type being classified and described in terms of:

i) its physical characteristics;

ii) how it is installed;

iii) where it is commonly used; and

iv) an estimate of its' proportional use.

In order to fulfill the requirements of phase one, the following agencies were consulted:

i) Manufactured Housing Association of Alberta (MHAA)

ii) Building Standards Branch of the Alberta Dept. of Labour

iii) Municipal authorities having jurisdiction for manufactured housing parks in Fort McMurray, Edmonton, Red Deer, Calgary and Lethbridge.

iv) Alberta Mortgage and Housing Corporation

v) Canada Mortgage and Housing Corporation

Finally, Phase One required the development of criteria which would be used to establish acceptable limits of surface foundation movements.

1.4.2 Phase Two

The study examined typical foundation systems which had been installed in Alberta over the past ten years. A principal objective of this phase was to survey and

monitor surface mounted wood block foundation movement, recording surface and subsurface temperatures of such foundations in Fort McMurray, Edmonton, Red Deer, Calgary and Lethbridge.

The monitoring and survey program included the following:

i) The installation or use of existing survey control monuments and two temperature probes at each monitored foundation.

ii) The measurement of movement and recording of temperatures at appropriate intervals, with a maximum of four weeks between readings over one winter season (1983/84).

iii) Determination of the general soils classification under the monitored foundations by means of a minimum of one test bore for each manufactured housing park considered.

iv) A qualitative assessment of the effects of foundation movement based on the periodic inspections of homes and interviews with the occupants.

v) Surveys were conducted using mailed questionnaires to groups of homeowners, park owners, building inspectors, and contractors.

vi) In each of the typical foundation systems in the five locations, foundation costs were to be determined (equipment, materials and labour) in consultation with a local MHAA Dealer.

1.4.3 Phase Three

Phase three assessed surface mounted foundations in Alberta based on analysis of phases one and two, experience in the industry, and engineering practice.

Conclusions and recommendations in the following areas are made:

a) limits of acceptable movement of manufactured housing foundations based on the results of the performance monitoring and surveys;

b) the acceptability of using insulated or non-insulated skirting as a means of minimizing the effects of frost penetration; and

c) the typical surface and subsurface foundation systems were assessed on the basis of their costs and performance.

2.0 Selection and Monitoring of Parks and Homes

2.1 Park Selection

2.1.1. Introduction

Attempts were made to select sites across the Province in which the conditions of the soil and foundation type were similar in order to facilitate analysis. The sites were selected in different geographical locations to compare a range of climates. Also sites were chosen which had frost susceptible soils.

2.1.2. Geographical Location

Alberta has a range of climatic conditions. In the northern areas, sub-zero temperatures and heavy snow falls are not uncommon. The middle region of Alberta, Edmonton to Calgary, experiences slightly less snowfall but the area can be subject to sub-zero temperatures aggravated by strong winds. The southern portion of Alberta, Calgary and south, experiences moderating winds during the winter, called chinooks, which often maintain air temperatures just above or below the freezing point. Mobile home parks located in Fort McMurray, Edmonton, Red Deer, Calgary and Lethbridge were chosen to provide the information required to determine the foundation performance.

2.1.3. Soil Types

Parks with soil most likely to exhibit frost heave due to the change in season were selected. These soils were generally comprised of silts in combination with clays, sands and gravels, which are known to be frost susceptible soils.

Foundations on rock, gravel and certain types of sand were not monitored as these soil types are generally not frost susceptible and pose little or no problem for mobile home foundations.

Organic soils have not been considered as they generally are not acceptable as a founding soil for mobile home foundations. An engineering evaluation is always required if owners, by necessity, establish a mobile park on this type of soil.

2.2 Mobile Home selection

In order to reduce the effects of variables influencing the results obtained from the field, the following factors were virtually kept the same:

2.2.1 Size

The size chosen for the mobile home was a single wide unit approximately 5 metres wide and 21 metres long.

2.2.2 C.S.A. Standard

All units were built to conform with C.S.A. Standard Z.240.2.1. - 1979

2.2.3 Foundation

The type of foundation chosen for study was surface mounted wood blocking. This system appears to be the most widely used type of support for homes in mobile parks. Sub-surface foundation systems extending below the level of frost penetration were not monitored.

2.2.4 Orientation

To obtain the maximum effect of the winter in terms of the deepest frost penetrations, homes were selected that were exposed to the prevailing wind and oriented longitudinally to present the greatest wall surface area to the north as possible. By selecting such homes, it was anticipated that the soil on the north side would remain frozen longer than the soil on the south side. It was felt that this would yield the greatest differential settlement possible on thawing.

2.2.5 Skirting

As the study was limited to the assessment of one housing unit from each of five mobile home parks, units were selected with enclosed crawl spaces with the uninsulated type of skirting. In the five parks selected for the study most homes were fitted with this type.

2.2.6 Illustrations

Photographs 1 to 5 inclusive on pages 6,7 and 8 show each mobile home monitored in the study. Photograph 6 on page 13 illustrates a ground water stand pipe and bench mark used in Red Deer to monitor ground water level. The bench mark established the datum from which differential movement of the wood block foundations were related. Photograph 7 on page 14 shows a typical thermistor installation.

2.3 Monitoring Method

Information as to the depth of frost penetration and the associated movement of the soil system resulting from the ice lense formation was obtained from temperature probes and level readings. The probes, fitted with strings of temperature sensing elements called thermistors, were installed at diagonal corners of the unit to measure frost penetration. In conjunction with the readings of these thermistors, vertical elevations of the homes' foundation were taken, referenced to a geotechnical bench mark or other permanent ground feature. The recording of the temperatures determined the rate at which the frost front advanced in the soil and the final depth to which the frost penetrated. Readings obtained on the vertical movement gave information on the amount the soil heaved as a result of ice lense formation.

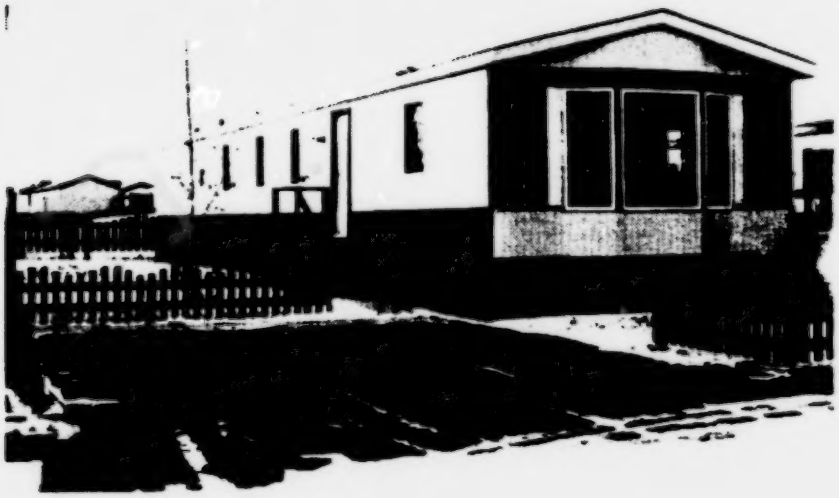
The report prepared by Hardy Associates (1978) Ltd. compiles all readings taken at the various sites and is attached as an appendix to this report.

Photograph 1: Fort McMurray - Cartier Trailer Court. 4.9m x 20.4m overall; fully skirted. Foundation type:surface mounted wood blocking on prepared fill soil base.

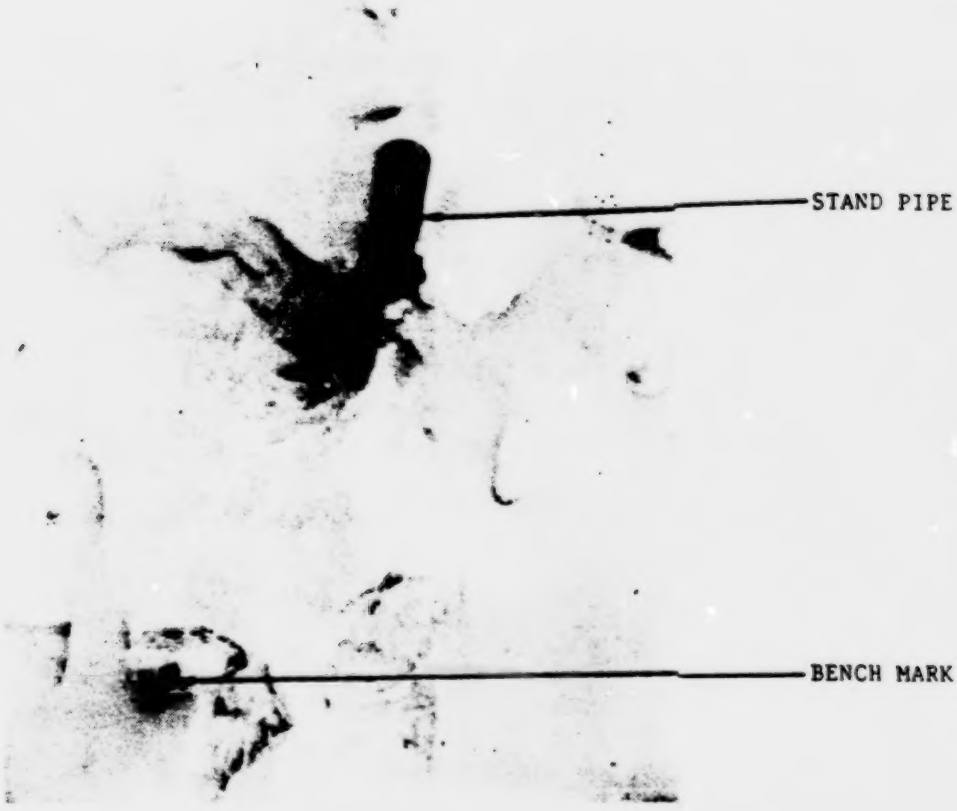
Photograph 2: Leduc - Willow Park Estates. 4.9m x 21.3m overall; fully skirted. Foundation Type: surface mounted wood blocking on prepared fill soil base.

Photograph 3: Calgary - Red Carpet Mobile Home Village. 4.9m x 21.3m overall; fully skirted. Foundation type:surface mounted wood blocking on prepared fill soil base.

Photograph 4: Red Deer - Parkside Mobile Estate. 4.9m x 21.3m overall; fully skirted. Foundation Type: surface mounted wood blocking on prepared fill soil base.



Photograph 5: Lethbridge - Parkview Estates.
4.85m x 21.6m overall; fully skirted. Foundation Type: surface mounted wood blocking on prepared fill soil base.



Photograph 6: Red Deer - Parkside Mobile Estate.
Ground water standpipe and bench mark ground rod.

Photograph 7: Parkside Mobile Estate - Red Deer.
Thermistor installation - southeast corner.

3.0 Review of Foundation Characteristics

3.1 Soils

3.1.1. Introduction

Soils, as an integral part of foundation systems, can be grouped and identified by their constituent particulate size. There are three major groups of soils:

a) Coarse grained soils - comprised of particles visible to the naked eye. They include gravels and sands.

b) Fine grained soils - soil particles which are not visible to the naked eye. They include silts and clays.

c) Organic soils - soils having a high natural organic content. They include soils formed in place by the growth and decay of trees, plants and other vegetation.

Clean coarse grained soils are non-frost susceptible. For the purpose of this study, these soils are not considered as they generally pose little or no threat on freezing or thawing to the mobile homes founded on them.

The organic soils, readily identified by their colour, odor, spongy feel and fibrous texture are generally unsuitable as a foundation soil.

3.1.2 Frost susceptible soils

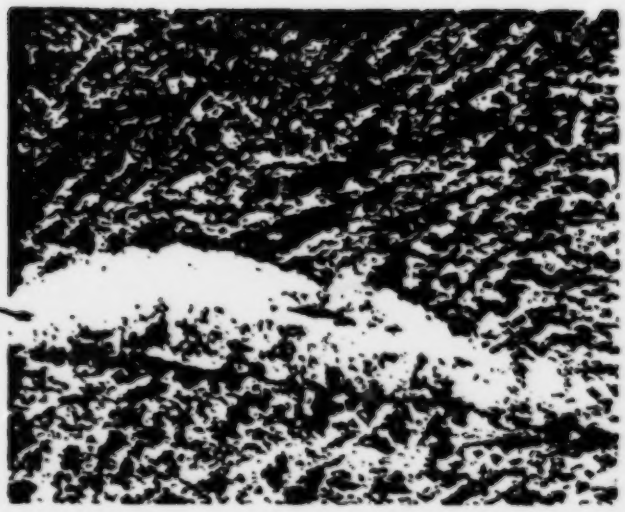
A frost susceptible type of soil is one in which the pores between the particles are small enough to permit capillary action, so that water will rise through it.

Ice lenses grow as a result of this water migration through the soil and continue to grow for as long as water is in sufficient supply and the temperature of the soil is below zero degrees celsius.

Frost susceptible soils are found in all areas of Alberta. A more in-depth study of factors influencing frost action in soils, theoretical depths of frost penetration and the theory of the freeze-thaw mechanism is covered in the report prepared by Hardy Associates attached as appendix A. A typical ice lense form in the soil is illustrated by photograph B, on page 17.

3.2 Foundation Systems

Foundations are designed to transfer superstructure loads to the soils on which or in which they are founded. The type of foundation used is determined by the bearing capacity of the founding soil, the intensity of the loads to be transferred and the allowable levels of settlement. These factors become less critical for small buildings particularly as to the bearing capacity of the soil.



Photograph 8: Typical ice lense formation
(cross-sectional view)

The superimposed loads or weights of mobile homes to be supported vary for various makes of units. Longitudinally, the mobile home weight is not evenly distributed over the floor surface because of the arrangement of the interior living areas. The kitchen area particularly has the largest weighted area and is often located near the center of the unit.

However, the average load per metre of mobile home length is estimated to be 5 kN/m (363 lbs. per ft.) This was derived from the units under study which averaged 21 meters in length and 5 meters in width and weighed approximately 11,400 kilograms (25000 lbs.).

An average foundation load for each foundation unit is therefore approximately 6.95 kilonewtons (1562 lbs.)for a unit having sixteen supporting foundation elements. This loading translates to 19.30 kilonewtons per square metre (390.5 lbs. per square foot) for a 600 mm square surface mounted wood block foundation. Most soils are capable of providing the bearing capacity to support such light loads.

The superstructure load is transmitted to the founding soil by various foundation types some of which are classified under the following headings.

3.3 Surface Mounted Foundations

3.3.1 Introduction

Foundation systems structured and placed on or just below the surface of soil or a prepared soil base are classified as surface mounted foundations. They are economical systems and somewhat subject to forces that can compromise their structural integrity. Being surface mounted they are not integral with the support soil.

More secure anchorage by means of soil anchors either as diagonal ties from the supporting chassis and/or transverse over-the-roof straps attached to soil anchors may be required in combination with surface foundations for safe guarding the unit against the effects of horizontal and uplift forces caused by high winds and floods. They are not dealt with in this report.

3.3.2 Wood blocking (Photograph No. 9)

Surface mounted wood blocking generally consist of 150mm x 150mm (6" x 6") untreated spruce wood blocks. Wood blocks are often utility grade rough or dressed lumber cut to form a crib of two members per plane, alternating with each pair at right angles. The wood is subject to some shrinkage as it dries out when placed beneath the housing unit it supports, however, the amount of shrinkage is usually not significant. Blocks are generally toe nailed together one to the other to prevent intra block movement. Levelling of the mobile home is achieved by wedge blocks and other shim pieces between the crib and the frame of the mobile home.

Photograph no. 9 Surface mounted wood block foundation showing results of wind shift

It appears most wood blocking is mounted directly on a levelled soil surface or on a prepared gravel bed. In some instances, the blocking is placed on concrete slabs set below the top of soil.

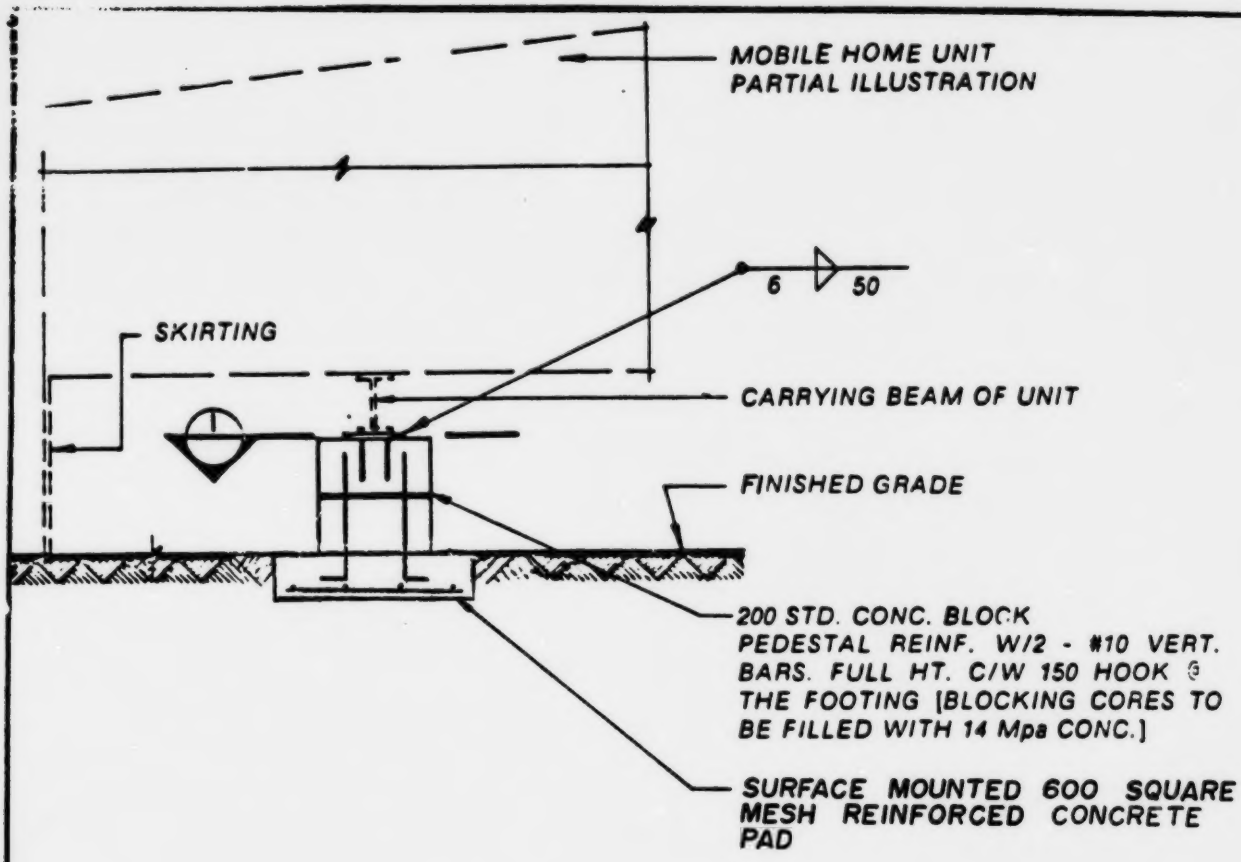
Photograph No. 9 on page 20 shows an actual wood block foundation found in use. This badly set foundation is subject to block shift relative to one another.

3.3.3 Masonry pedestals (Drawing No.1)

Drawing No. 1 on page 22 illustrates the general configuration of the masonry pedestal foundation as a surface mounted type.

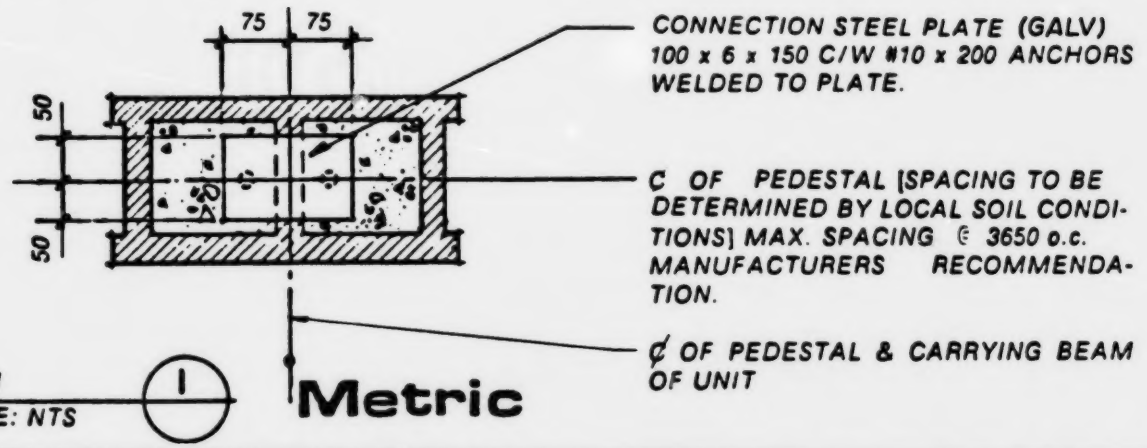
This type of founding element serves the manufactured housing industry in much the same manner as the wood block foundation. It is much more durable than the wood block system but requires more preparation of the in-situ soil for its use. The masonry pedestal is superior to the wood block system in that it is heavier when fully grouted and thus provides for a more positive gravity weight to anchor the mobile home unit.

A major disadvantage with the masonry foundation is the cost and the availability of a tradesman to erect the blocks particularly in rural areas. It is not often used. Responses indicate only 1% to 3% of all foundation elements are masonry.


MOBILE HOME UNIT
PARTIAL ILLUSTRATION
6
50
SKIRTING
CARRYING BEAM OF UNIT
FINISHED GRADE
200 STD. CONC. BLOCK PEDESTAL REINF. W/2 - #10 VERT. BARS. FULL HT. C/W 150 HOOK @ THE FOOTING [BLOCKING CORES TO BE FILLED WITH 14 Mpa CONC.]
SURFACE MOUNTED 600 SQUARE MESH REINFORCED CONCRETE PAD

PARTIAL CROSS-SECTION

SCALE: NTS


75
75
50
50
CONNECTION STEEL PLATE (GALV) 100 x 6 x 150 C/W #10 x 200 ANCHORS WELDED TO PLATE.
℄ OF PEDESTAL [SPACING TO BE DETERMINED BY LOCAL SOIL CONDITIONS] MAX. SPACING @ 3650 o.c. MANUFACTURERS RECOMMENDATION.
℄ OF PEDESTAL & CARRYING BEAM OF UNIT

PLAN

SCALE: NTS

Metric

		DRAWN BY
		CHECKED BY
	SURFACE MOUNTED CONC. BLOCK PEDESTAL	DWG. NO. 1

3.3.4 Prefabricated Metal Stands

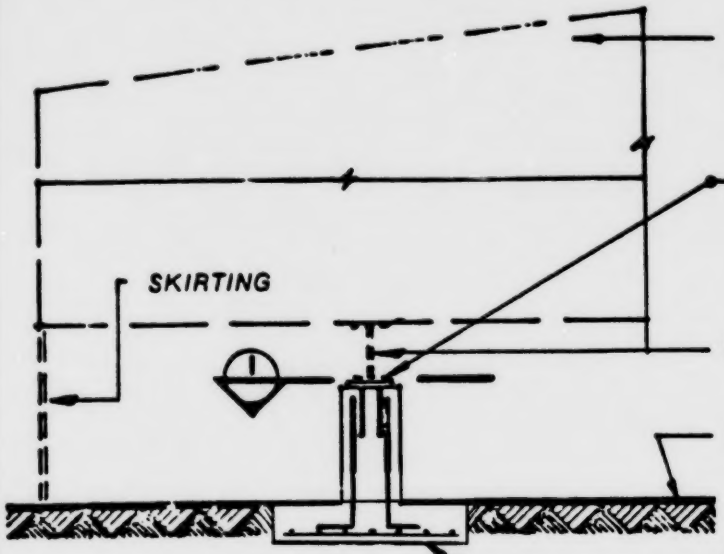
Prefabricated metal stands can be made in many styles and combinations. Any form of metal support intended for use as a surface mounted footing will generally require proper seating on the soils by means of metal plates and/or concrete pads. It should be constructed to support the mobile home without undue settlement and buckling of members.

The major advantage of this type of founding element is its durability and, if designed well, its ease of adjustment in correcting differential settlements. Metal founding elements can also be designed to provide greater stability against overturning and sliding under strong wind loads.

Examples of this type of support for mobile homes were not found in the surveys. They are known to exist but an estimate of their use is difficult to determine.

3.3.5 Concrete Pedestals (Drawing No. 2)

Surface mounted reinforced concrete pedestals supported by concrete slabs-on-grade or concrete footings serve the foundation needs of mobile homes very well.



PARTIAL CROSS SECTION

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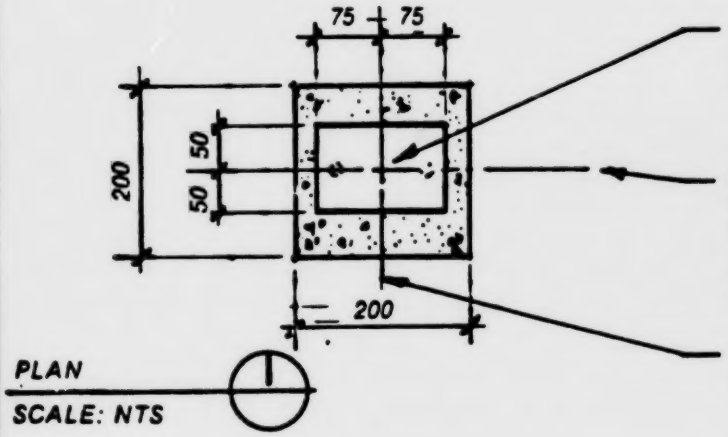

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	SURFACED MOUNTED POURED CONC. PEDESTAL	DWG. NO. 2

In terms of lateral superimposed loads, the pedestal type will provide greater resistance to overturning of the unit, and, with anchorage to the concrete footing, to sliding. In most cases a mobile home supported by this type of foundation system will suffer the same differential settlement as other surface mounted foundation systems.

This foundation type was not found to be used often in Alberta.

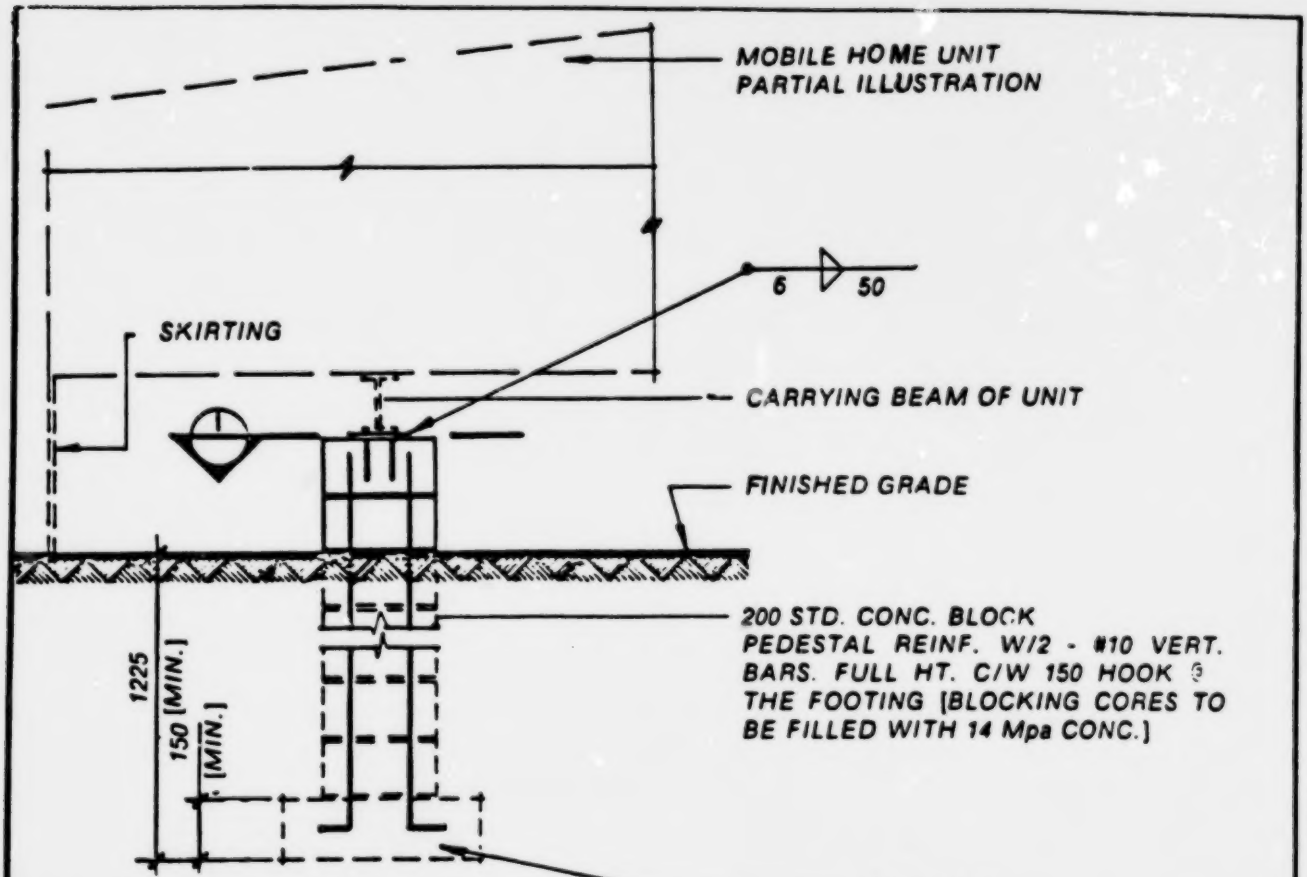
A few contractors indicated the cost of this foundation would be high.

3.4 Sub-Surface Foundation Types.

3.4.1 Masonry Pedestal (Drawing No. 3)

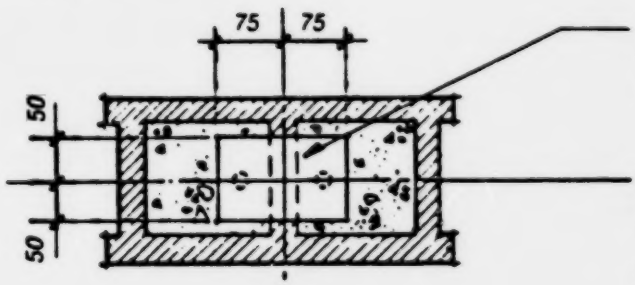
The same remarks on the surface mounted masonry pedestals apply to the deep pedestals with the exception that the deep masonry pedestals provide greater safety against uplift and large settlements in instances where the footing is placed below the level of frost penetration.

Excavation of the holes must provide for additional area for a tradesperson to work and to install the blocks and care must be exercised in compaction to avoid subsidence of the backfill or damage to the pedestal. It would be a much more expensive foundation system to install compared to the surface mounted type. It is evidently not a popular system; indications of its proportional use range between 1% to 3%.


MOBILE HOME UNIT
PARTIAL ILLUSTRATION
6
50
SKIRTING
CARRYING BEAM OF UNIT
FINISHED GRADE
200 STD. CONC. BLOCK PEDESTAL REINF. W/2 - #10 VERT. BARS. FULL HT. C/W 150 HOOK @ THE FOOTING [BLOCKING CORES TO BE FILLED WITH 14 Mpa CONC.]
1225
150 [MIN.]
[MIN.]
CONC. FTG.

PARTIAL CROSS-SECTION

SCALE: NTS


75
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CONNECTION STEEL PLATE (GALV) 100 x 6 x 150 C/W #10 x 200 ANCHORS WELDED TO PLATE.
℄ OF PEDESTAL [SPACING TO BE DETERMINED BY LOCAL SOIL CONDI-TIONS] MAX. SPACING @ 3650 o.c. MANUFACTURERS RECOMMENDA-TION.
℄ OF PEDESTAL & CARRYING BEAM OF UNIT.

PLAN

SCALE: NTS

1

Metric

		DRAWN BY
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	SUB-SURFACE CONC. BLOCK PEDESTAL	DWG. NO. 3

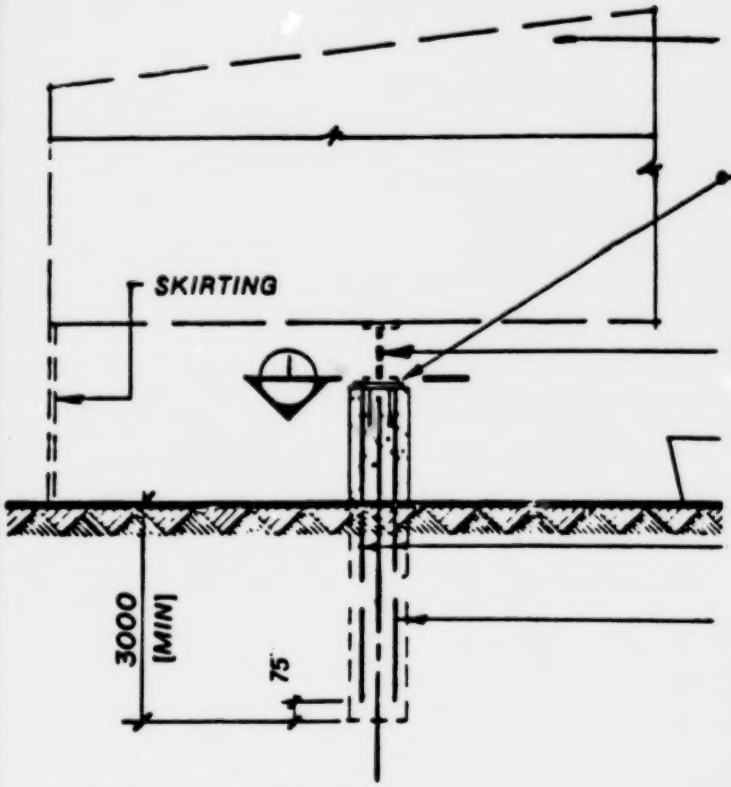
3.4.2 Drilled Reinforced Concrete Pile (Drawing No. 4)

This type of founding element is suited for use in areas of high winds and when a permanent foundation is required. Once the piles have been drilled and cast, this system will not lend itself to be removed economically. The concrete pile prevents overturning and sliding due to high winds by reason of its structural stability and minimizes greatly the differential settlement experienced by surface or near surface mounted foundation systems previously discussed.

Concrete piles are expensive; this system requires a drilling machine, such as a truck mounted auger similar to that used for erecting poles for carrying telephone and power cables.

Once placed correctly they will endure for the life of the mobile home and be generally trouble free. The foundation system provides positive anchorage for the home. Indications are that the use of concrete piles as a founding system is about 7% of the foundation systems in use in the Province.

There are certain soils of high silt content and inorganic clays of high plasticity where this pile system should only be used under the direction of a professional engineer.



PARTIAL CROSS SECTION
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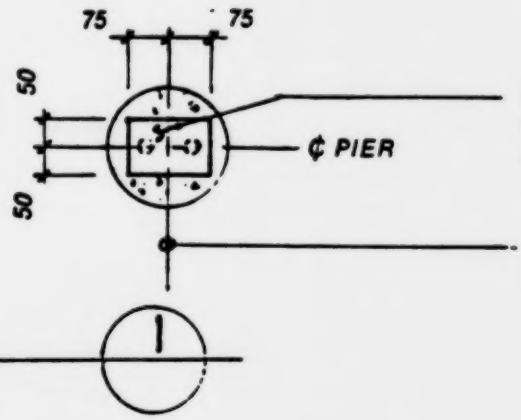

PLAN
SCALE. NTS

		DRAWN BY
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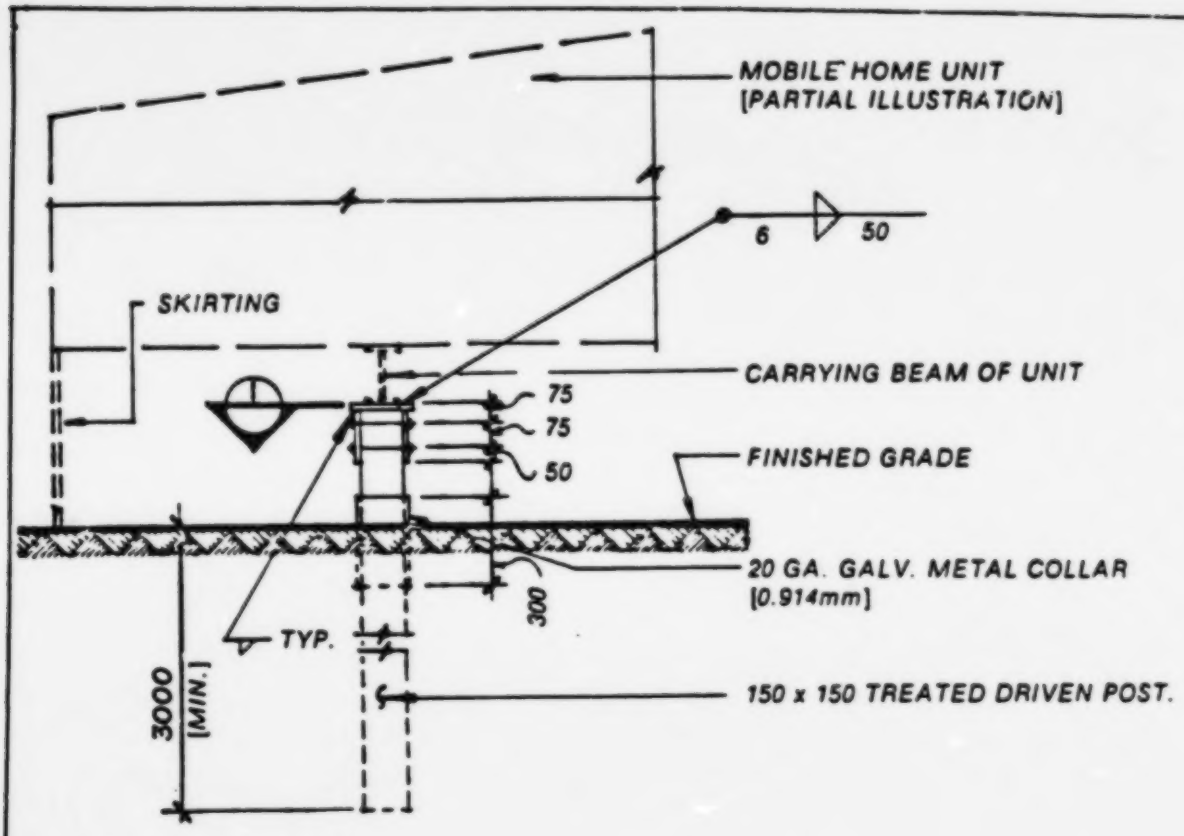
	DRILLED CONC. PIERS	DWG. NO. 4

3.4.3 Pressure Treated Wood Piles (Drawing No. 5)

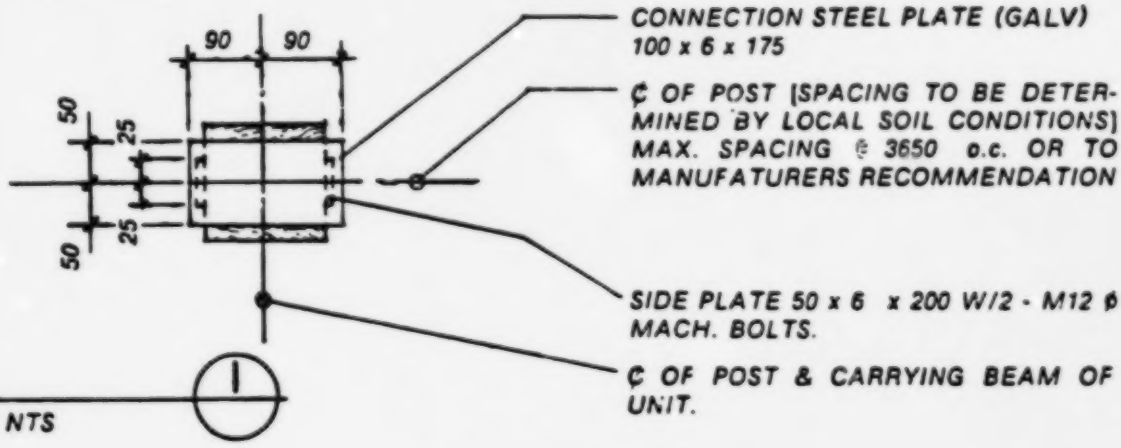
Timber piles have long been a common system of supporting buildings. They are a practical type of foundation system for soils deficient in bearing strength and generally would be suitable for some of the soil types outside the scope of this study, such as soft clays and fibrous soils. The timber piles are treated to safeguard against wet and dry rot and other forms of organic attack.

Its value as a supporting foundation is very good and will provide the same lateral stability as a concrete pile. Correctly installed, well treated wood piles will have a life expectancy of twenty five years or more. Its percentage use as a foundation system was not determinable.



PARTIAL CROSS-SECTION
SCALE: NTS

Metric


90
90
50
25
25
50
CONNECTION STEEL PLATE (GALV)
100 x 6 x 175
℄ OF POST (SPACING TO BE DETERMINED BY LOCAL SOIL CONDITIONS)
MAX. SPACING @ 3650 o.c. OR TO MANUFATURERS RECOMMENDATION
SIDE PLATE 50 x 6 x 200 W/2 - M12 ϕ MACH. BOLTS.
℄ OF POST & CARRYING BEAM OF UNIT.

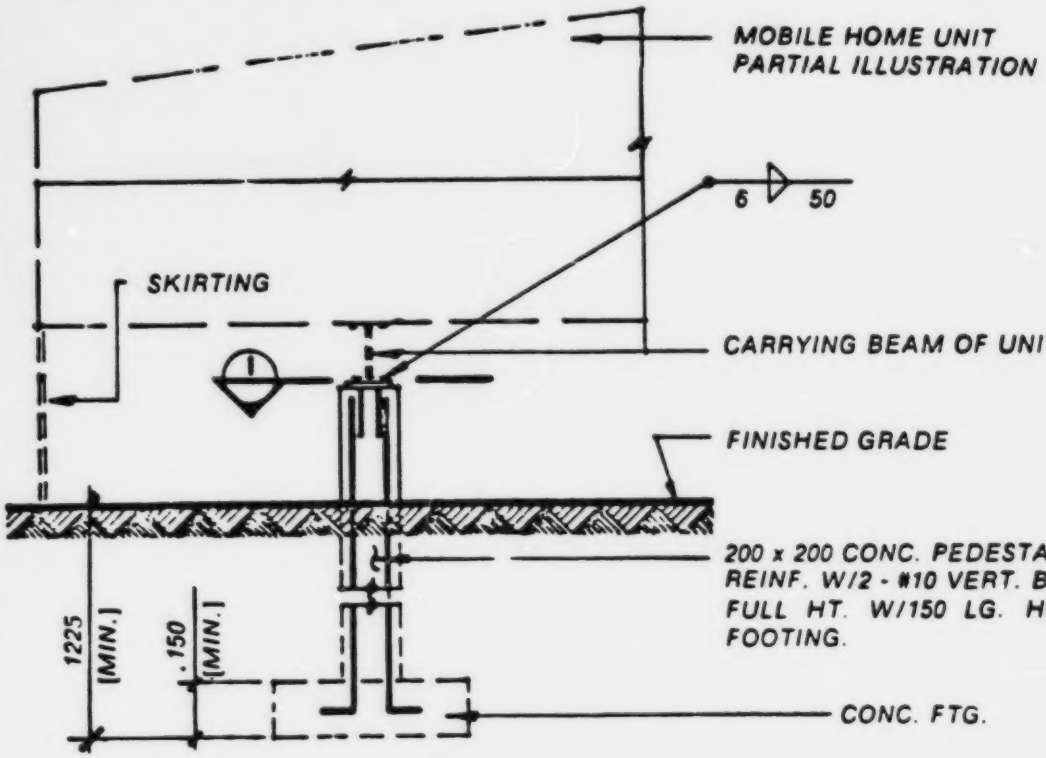
PLAN
SCALE: NTS

		DRAWN BY
		CHECKED BY
	PRESSURE TREATED DRIVEN WOODEN POST	DWG. NO. 5

3.4.4 Concrete Pedestals and Footings (Drawing No. 6)

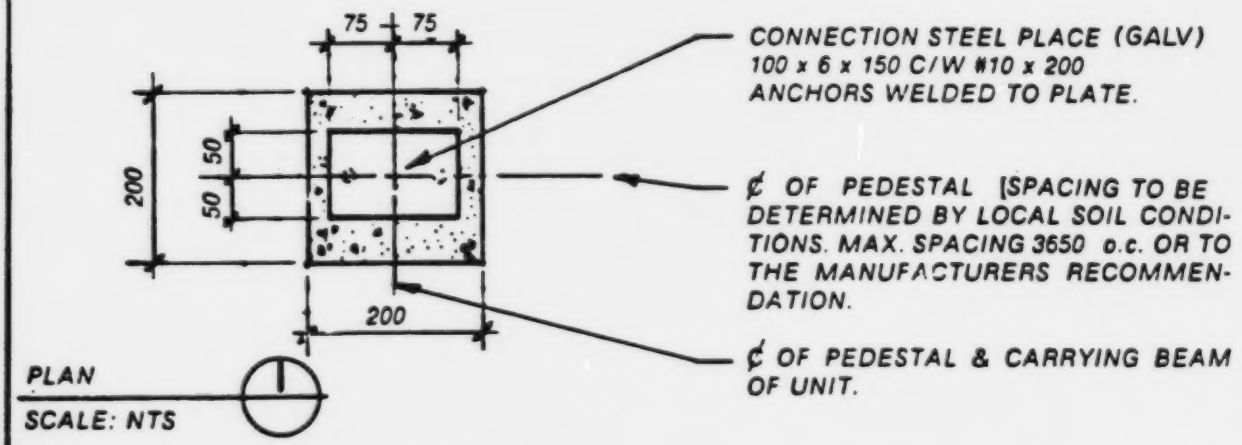
Comments made on the surface mounted concrete pedestals and footing equally apply to the subsurface type.

A well designed deep seated concrete pedestal and footing formed in an excavated hole below the zone of seasonal change will provide good support and protection against sliding and overturning caused by wind forces as well as heave due to ice lense formation.



PARTIAL CROSS SECTION

SCALE: NTS



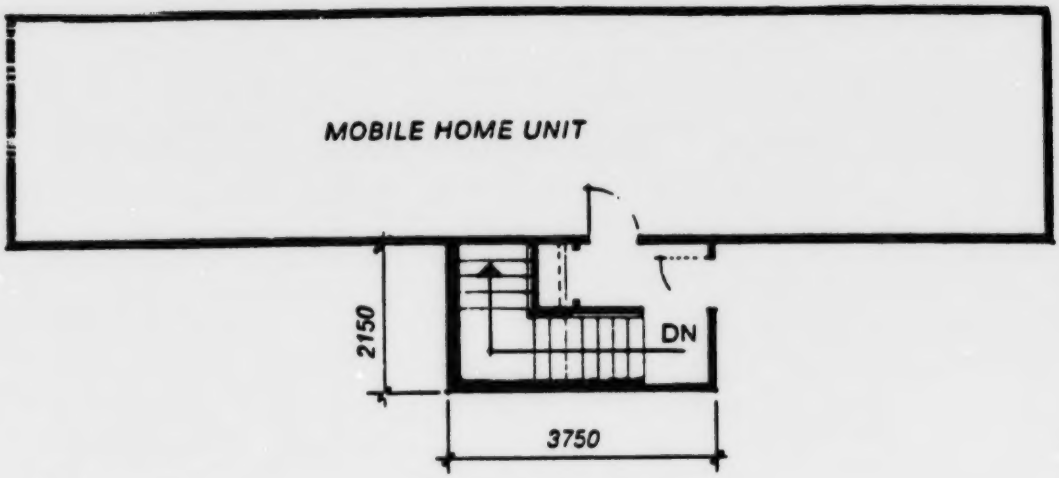
PLAN

SCALE: NTS

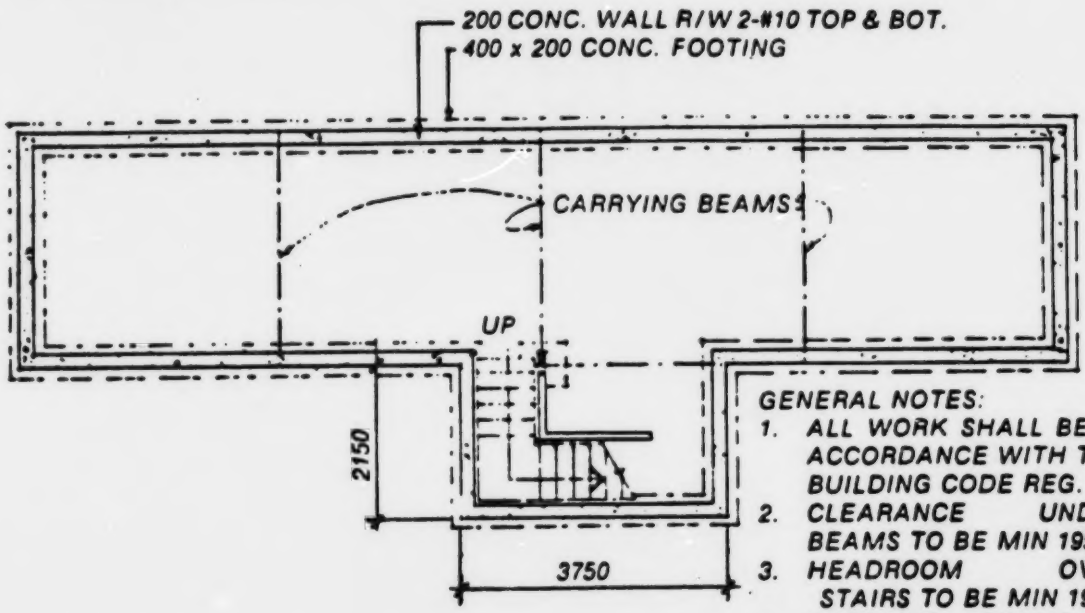
		DRAWN BY
		CHECKED BY
	SUB SURFACE POURED CONC. PEDESTAL	DWG. NO. 6

3.4.5 Formed Reinforced Concrete Foundation Walls (Drawing No. 7)

This foundation is noted here as a possible alternate foundation system. It is used primarily in sub-divisions providing economical housing of a permanent nature. This type of structure is developed for the purpose of providing additional living area as well as support to itself and the superimposed mobile home. It is a combination of sub-structure and a continuous concrte strip footing, the cost of which is very high in comparison to the individual units of support previously mentioned.



FLOOR PLAN



FOUNDATION PLAN

GENERAL NOTES:

1. ALL WORK SHALL BE IN ACCORDANCE WITH THE BUILDING CODE REG.
2. CLEARANCE UNDER BEAMS TO BE MIN 1950
3. HEADROOM OVER STAIRS TO BE MIN 1950
4. CARRYING BEAMS & PLACEMENT TO BE DESIGNED TO THE MANUFACTURERS RECOMMENDATIONS.

Metric

		DRAWN BY
		CHECKED BY
	CONCRETE FOUNDATION WALLS	DWG. NO. 7

4.0 Factors That May Affect Foundation Movement

4.1 Introduction

The factors considered to be of major importance are the type of bearing soil, foundation system, siting, weather and soil temperature.

4.2 Mechanics of Soil Support

The distribution of applied loads to foundation soils can be resolved into a resultant force which can be separated into vertical and horizontal components and moments. The vertical component is resisted by the soil in compression. It is generally a component of several loads, such as the weight of the structure, the vertical component of a wind force or the forces due to frost heaving or subsiding soils or of other types of loading.

The horizontal component of load similarly is resolved from the same resultant force and is resisted by the soil in the following manner:

i) By the foundation exerting lateral pressure on and being resisted by the soil mass.

ii) By shear developing in the soil mass along the base of the structure.

Both vertical and lateral forces cause movement of the foundation element, horizontally, vertically and rotary. Figures 1 through 4 are illustrative of these types of movement.

Fig. 1 on page 38,represents a condition of equilibrium in which only a vertical load is applied on the foundation. Generally this is the gravity weight of the mobile home acting concentrically with the foundation, producing an equal and opposite resultant reaction force in the soil. No movement will take place if the bearing capacity and character of the the soil is sufficient to sustain the imposed load of the mobile home without consolidating the soil.

Fig. 2 on page 38,illustrates what basically happens in frost susceptible soils. As the ice lense grows, an uplift force P is generated which very often is off center of the foundation. The resolution of this force may be interpreted as a vertical force equal to P acting on the center of the footing plus a couple (moment) equal to M=Pe, in which e is the distance to the actual force resultant of the frost heave.

The action of frost heaving results in an uplift and a rotation of the wood blocking. There is associated horizontal movement of the footing with frost heave, the degree of movement being dependant on certain soil factors, secondary moments due to lateral movement of the superimposed loads, wind forces, other vertical forces, and the influence of other units of wood block foundation supporting the mobile home. Discussion of the combined effects of these forces however, are complex and are outside the scope of this report.

Vertical movement in the order of up to 125mm is not uncommon in frost susceptible soils. Heaving resulting from ice lense growth could exceed 185mm if all the conditions necessary for growth are present. That is: an

unlimited supply of ground water, subsoils of sufficient capillarity and a temperature drop that will cause freezing. In reality, the soil systems in Alberta are such that the main action of heaving is confined to the upper 1.2m to 1.8m of the soil mass.

The converse to heave of course, is subsidence or settling. This phenomenon occurs when the frost front dissipates in the ground due to increased temperatures of late spring and summer. Ice lenses melt, and in melting leave a void and/or softened soil which is unable to support the imposed load of the mobile unit. Consequently settlement of the foundation takes place and in some instances, "re-levels" the floor of the mobile unit to within acceptable tolerances. In the severe case, the foundation element settles "beyond" an earlier level. This is a time dependent event. When the soil is subjected to continuous periods of alternately freezing and thawing, it continues to "break down" structurally on thawing. A common example of such time dependent settlement is the sidewalk of a fixed residence. With each season, depending on the season's severity in temperature and moisture, the sidewalk settles to one side, generally that side bordering the house, getting progressively worse as each year passes.

Wind forces work on wood blocking in much the same manner as frost heave. The action however, is much more rapid and involves impacting the soil mass due to relatively rapid loading and unloading in gusty winds. Figures 3 & 4, on page 40 illustrate this action.

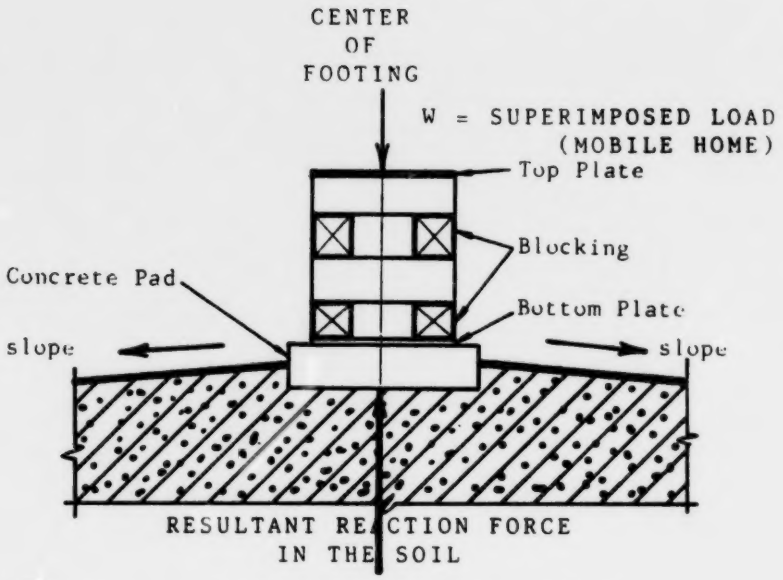


FIG 1 - INITIAL FOUNDATION SETTING

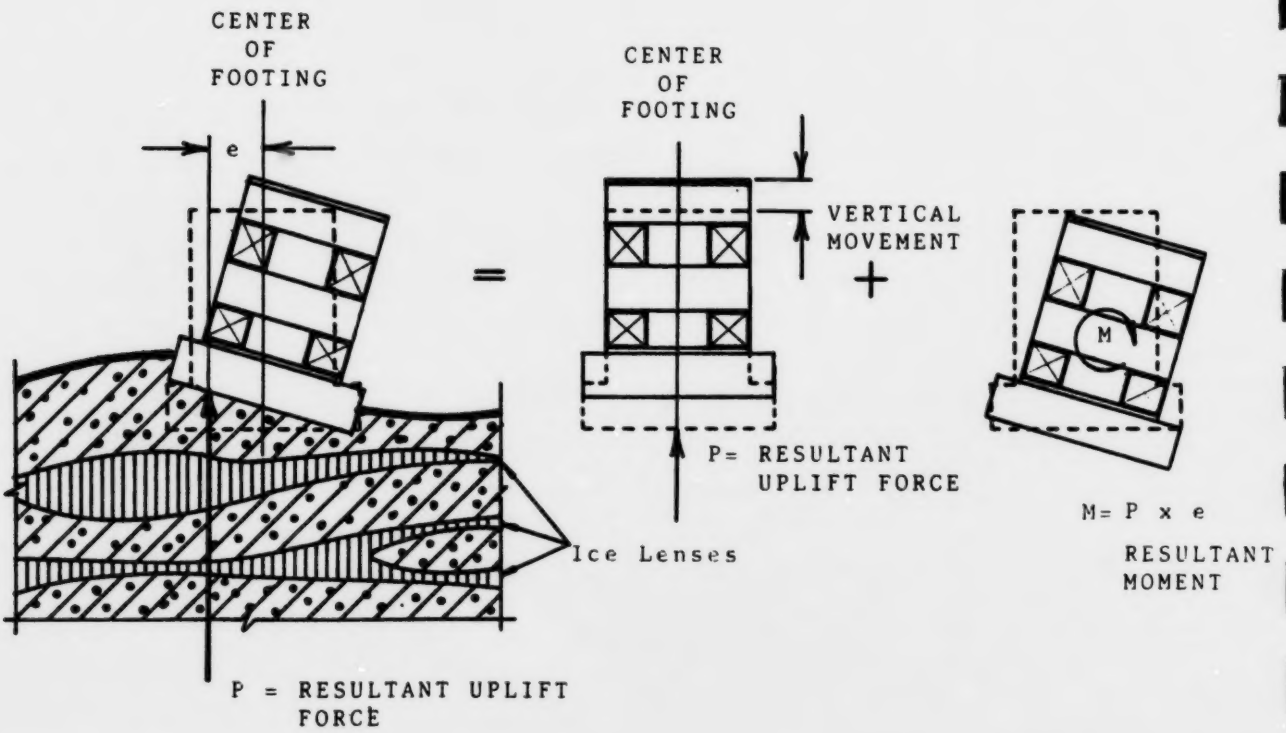


FIG 2 - FOUNDATION MOVEMENT DUE TO ICE LENSE GROWTH
IN FROST SUSCEPTIBLE SOILS
SCHEMATIC
(Assuming no internal displacement
of blocking in pier)

Fig. 3 on page 40 shows pictorially the external forces due to gravity loads of mobile unit and wind. Essentially, the wind effect on the foundation is one of primarily sliding the wood blocking laterally. Assuming the mobile unit and wood block foundation act as one, rotation of the foundation is likely to occur as shown in fig. 4. This is a simplification of the actual movement of the foundation. In reality the force situation produces a much more complex movement. However, in terms of movement both horizontally and vertically, the described movements constitute the largest portion of the actual movement the foundation is likely to experience.

Vertical forces due to the gravity loads of the manufactured home are generally very light, being in the order of 6.6 kilonewtons per foundation support or an equivalent pressure of approximately 12 kilopascals for most surface mounted footings. In contrast to these gravity forces, the pressure exerted by frost susceptible soils on freezing have been measured up to 200 KPA.

A preferred condition for founding soils then, is that they should not be frost susceptible.

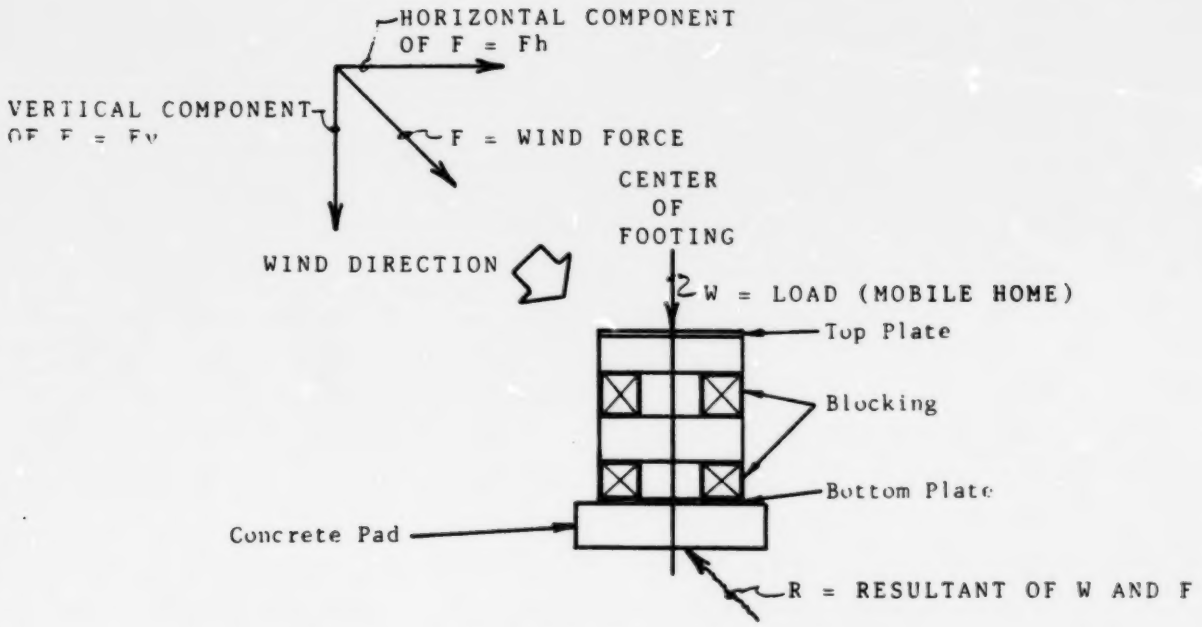


FIG 3 - INITIAL FOUNDATION SETTING

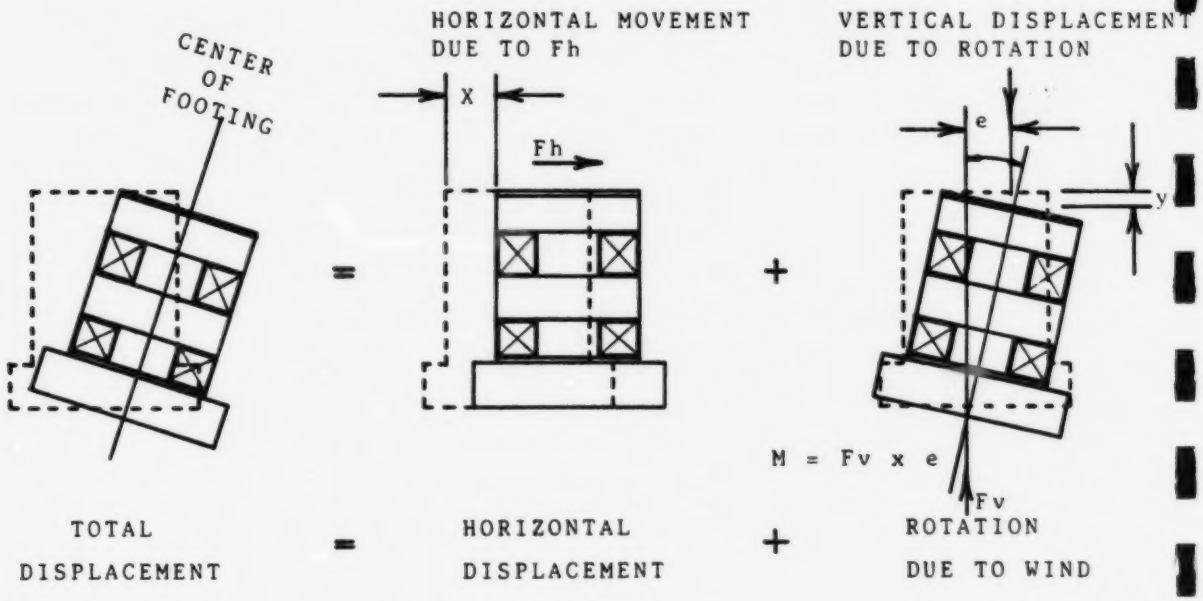


FIG 4 - FOUNDATION MOVEMENT DUE TO WIND ACTION
SCHEMATIC
(Assuming no internal displacement of
blocking in pier)

4.3 Foundation Types

The magnitude of movement and the influence of that movement over the frame of a mobile home are important factors since they determine, in conjunction with the soil character, the type of foundation to be selected.

Sub-surface foundations are the type of foundation system least affected by seasonal change in the upper layers of frost susceptible soils when extended beyond the depth of the frost front. Certain geotechnical factors must be taken into consideration in their design. Some geotechnical considerations involve adfreezing, overburden weight and water table level. If designed and constructed properly, sub-surface foundations will, in most instances, prevent movements due to frost heave and provide safety against other forces to which mobile homes are often subjected.

Surface mounted foundation systems will always suffer frost heaving and subsequent subsidence of the soil mass whenever the soil freezes readily and is accompanied by ice lense growth and thaw. However, the overall effects of this phenomenon are somewhat ameliorated by the small area of soil covered by the foundations.

The preferred condition for a foundation system based on frost susceptible soils, is that it should be below the zone of seasonal change and designed to eliminate or minimize the effects of seasonal change in the soils.

4.4 Orientation and Protection

A mobile home in a park that is sheltered will naturally suffer less from the lateral forces generated by the wind. With this shelter, the settlement of the leeward foundations are less likely to exceed the settlement of the windward foundation. The differential settlement between the foundation units are therefore less in a wind protected home for settlement caused by wind forces.

Shelter may be provided by trees, shrubs and berms. Units oriented to present the least wall surface to the prevailing wind will also suffer less the effects of the lateral forces generated by the wind.

To minimize differential settlement due to wind, **the park should provide as much protection as possible** and the soil base should be prepared well in order to minimize the constant loading and unloading of the foundation system as a consequence of the wind gusting.

4.5 Skirting

In assessing the value of insulated skirting versus a non-insulated skirting consideration must be given to whether or not:

a) the crawl space is heated; and

b) if the skirt is tight to the ground and sealed to prevent the flow of air in or out of the crawl space.

If the crawl space is sealed to prevent air escaping then an insulated skirt could provide for an environment which would inhibit frost penetrating the soils immediately below the mobile home. Heat of course, would have to be provided or permitted to enter the crawl space. Designed ventilation will have to be installed to avoid the occurrence of condensation within the crawl space. **A method to reduce the potential of frost heave is to heat the soil beneath the unit by using insulated skirting surrounding a heated crawl space.**

5.0 Criteria for Acceptable Limits of Foundation Movement.

5.1 Introduction

Manufacturers of mobile home units are required to conform to C.S.A. standards. Therefore it is assumed the mobile home units considered in this study can satisfactorily meet the minimum strength requirements and construction tolerances for these standards and safely sustain movements of large proportions before structural collapse is imminent.

The subject of allowable deformations that a mobile home can safely tolerate is very complex. In determining the structural limit, much more information is needed, particularly if the determined limit is to be of practical use.

The determination of the movement of a mobile home which is acceptable to the occupants is subjective and variable.

5.2 Structural Limits

In order to discuss the damage to the structure of a mobile home likely to be caused by frost heave, it will be necessary to obtain much more information than that obtained by this study. Only minimal damage to a monitored unit was found at Fort McMurray. It is the only instance of damage that can reasonably be attributed to frost heave.

Study of this unit indicates that the decisive factor in determining the limits of movement of the foundation will be the differential elevation between two points on the floor and the distance between these two points. This is called the angular distortion of the floor. For mobile homes it is suggested that an angular distortion of 10 mm in 3 meters be a tolerable limit, (expressed as a ratio, this limit equates to 1:300).

This limit, based on the generally accepted principle in the building industry as the deflection limit at which first cracking in plaster panels is to be expected, will be achieved when the mobile home tilts as a result of foundation elements settling with a differential movement of 17 mm between two points 5.0 meters apart or a differential movement of 72 mm between two points 21.587 meters apart. The lengths quoted being the shortest and longest distances between the two points of a 5 meter wide 21 meter long mobile unit.

More in depth field studies than those conducted in this report are required to substantiate such suggested limits.

5.3 Liveability Limit

While it may be that an angular distortion of 1:300 (10 mm in 3 meters) will prove acceptable from a structural viewpoint, occupant tolerance for this degree of differential settlement may be somewhat different. Results of the survey (Question 24) indicates floor slopes ranging from 1:480 to 1:80 were acceptable to 18 out of 19 respondents. Only one respondent complained of a slope 1:240; that is 12 mm in 10 meters.

6.0 Review of Foundation Performance in the Field.

6.1 Introduction

Information on the performance of foundations was gathered from selected sites by field study and a survey of mobile home owners, park managers, building inspectors and contractors.

The field study, prepared and executed by Hardy Associates (1978) Ltd., resulted in a report containing information on soil temperatures and elevation of the foundation system for each of the selected units. The results of the field findings, due to the mild winter, are of little value in determining the maximum heave a foundation could experience.

6.2 Review of Monitored Units

6.2.1 Field Monitoring - Frost Penetration.

The deepest penetration of the frost front was recorded at Fort McMurray. The frost reached a depth of 2.45 meters March 9th, being driven to a maximum depth 2.6 meters by May 1st, while the upper layers of soil experienced thaw action from April 5th on.

Frost penetration was a maximum on the north side of the monitored unit and frost dissipation in the soil was delayed approximately one month in comparison to the south side. Dissipation may well have been accelerated by the heavy rainfall reported to have fallen about May 5th 1984.

At Leduc, the formation of ice in the frost susceptible soil was confined to the near surface layers. The frost front advanced to a depth of 1.14 meters by February 28 and was dissipated by April 27.

The Red Deer field site recorded a frost penetration of slightly greater than 1.42 meters from readings on the B thermistor string. The location of this thermistor string is the northwest corner of the mobile unit. By contrast, the A thermistor string located at the southeast corner of the unit, recorded a maximum frost penetration of slightly less than 1.14 meters. The soil is sandy in nature, and non-frost susceptible. Moisture content was low in the near surface soils (to one metre) increasing moderately with depth.

The Calgary home was founded on frost susceptible low plastic silty clay. Moisture content of the soil was fairly steady to a depth to 3 meters. It would appear from the field observations the frost front advanced only to a depth of 0.9 meters as recorded by the No. 2 string, located at the south end of the unit.

Readings taken at Lethbridge indicate frost penetration was near surface depth, the lowest temperature being recorded was 0 C at 300 mm below surface level. The soil beneath the unit monitored is frost susceptible with a moisture content of approximately 15%.

6.2.2 Field Monitoring - Vertical Movement

The only location indicating any significant vertical movement of wood blocking due to ice lense formation was found at Fort McMurray. The largest heave was on the near

corner foundation supporting the side exposed to the prevailing north-westerly winds.

Angular distortion of 1:223, 1:294, 1:300 and 1:477 are calculated from reported results in Fort McMurray. These are shown in figure 5 on page 50. No structural damage was evidenced by this movement. The only damage reported was the development of hairline cracks in the wallpaper, and doors being somewhat difficult to open.

The corresponding heave in the soil due to ice lense formation, was experienced as a 75 mm uplift at bench mark 3 and 31 mm at bench mark 4. The relationship between frost penetration and heave is shown in figure 6 and figure 7 on pages 51 and 52.

The results obtained from the other locations selected for monitoring are not significant. The maximum recorded vertical movement was 7 mm at Lethbridge. The maximum differential movement produced an angular distortion of recorded was 6 mm at Red Deer. This differential movement produced an angular distortion of 1:2055 between bench marks 7 and 11. Such distortion is of no consequence and in all probability would not be noticed by the occupants.

FOOTING ELEVATION

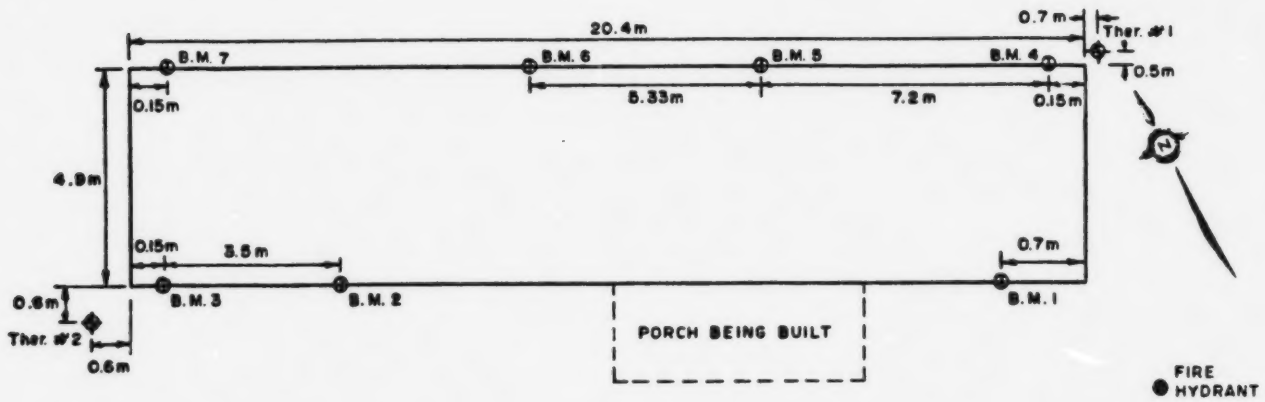
CLIENT: J. M. Mulligan & Associates Ltd.

PROJECT: Assessment of Manufactured Housing Foundation Systems
Cartier Trailer Court

LOCATION: 140 Clausen, Lot 15, Blk. 26, Plan 8121566, Fort McMurray

BENCHMARK: Fire Hydrant, Elevation 360.462 m

PROJECT No.: EG-05830.1



BENCH MARK TO BENCH MARK	ELEVATION DIFFERENCE	ANGULAR DISTORTION
3 - 7	22 mm	222.73
3 - 6	36 mm	250.56
3 - 5	46 mm	300.00
3 - 4	44 mm	470.23
2 - 7	15 mm	401.33
2 - 6	29 mm	168.97
2 - 5	39 mm	271.79
2 - 4	37 mm	467.64
1 - 7	26 mm	775.00
1 - 6	12 mm	1187.50
1 - 5	2 mm	4130.00
1 - 4	4 mm	1207.50

Figure No: 5

THERMISTOR #1 FOR T McMURRAY (REFERENCE FIGURE 5)

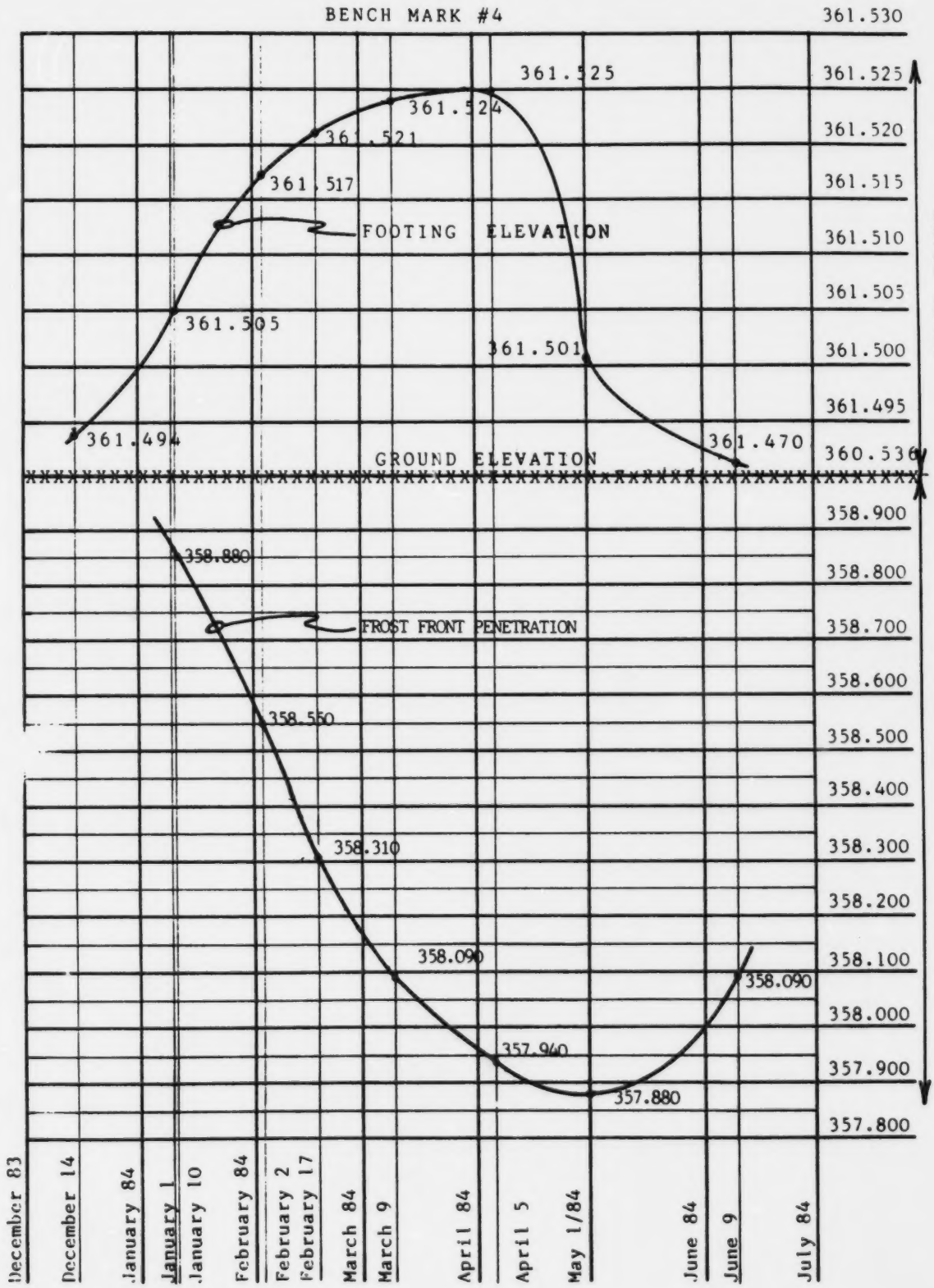


FIGURE 6

FIGURE 6

THERMISTOR #2 FORT McMURRAY (REFERENCE FIGURE 5)

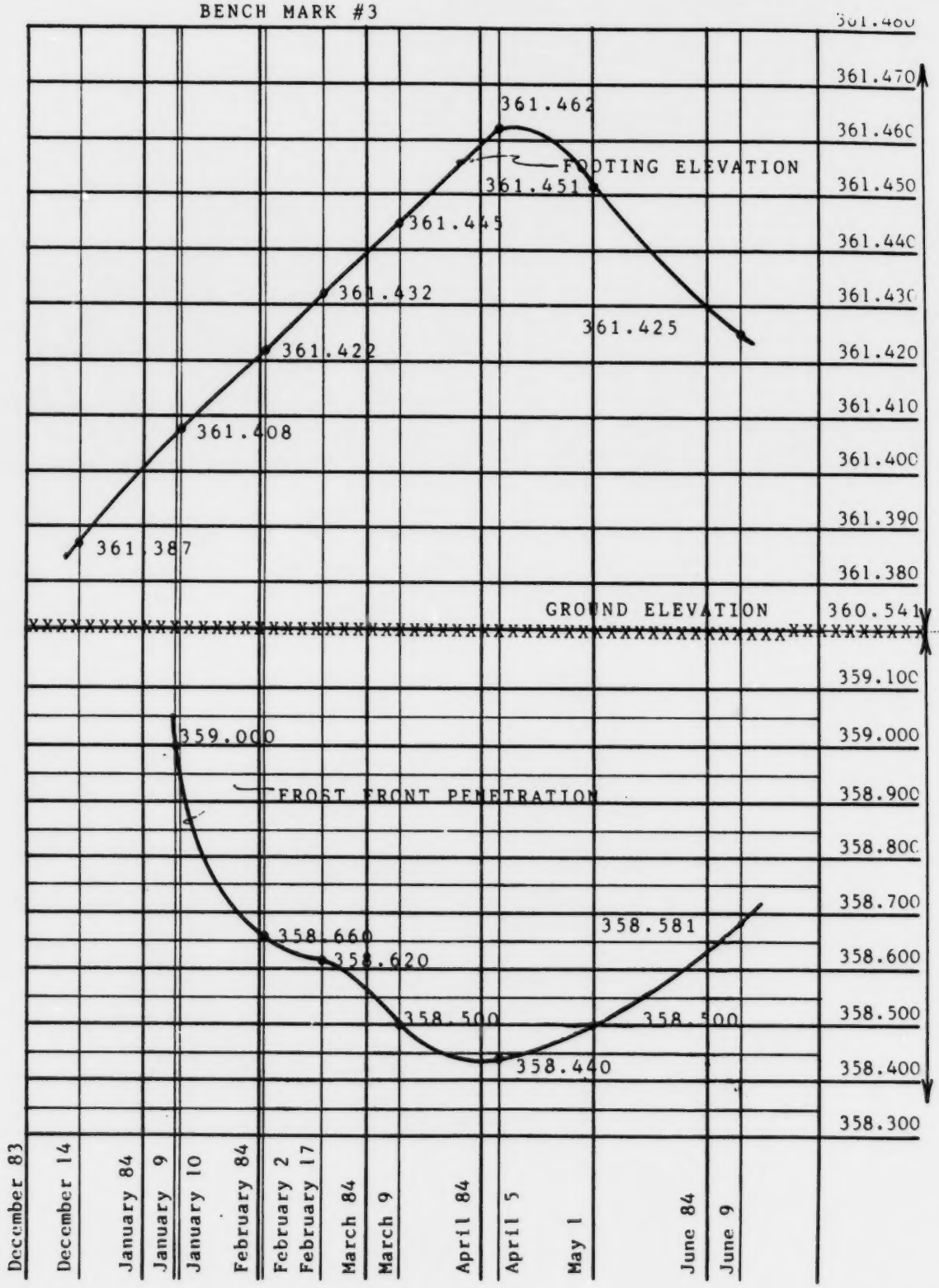


FIGURE 7

7.0 Summary of the Survey Responses

7.1 Introduction

A sample of 324 home owners, 250 park managers and 150 building inspectors were identified. Responses were received from 78 home owners, 54 park managers and 74 building inspectors. The returns were small but well distributed within the Province. The survey sought to obtain information on the effects the climate of Alberta has on foundation systems supporting mobile units, in particular, the effect of ice lense growth in frost susceptible soils.

7.2 Summary Analysis

Dwelling Unit Characteristics:

1) Information has been gathered from a significant number of home owners (58%) that have lived in mobile homes manufactured prior to the 1979 C.S.A. standard requiring increased floor insulation (R26.7).

2) Some 63% of the respondents live in units 4.3 metres wide (14 feet) which is a standard unit width for the mobile home industry. Additions to these units appear to have been built to 63% of the units reporting.

3) The average weight of a 4.3m x 21.3m (14 ft. x 70 ft.) unit was 11,400 kilograms (25,000 lbs.) while 5.0m x 21.3m (16 ft. x 70 ft. units weighed 15,000 kilograms (33,000 lbs.)

Foundation Characteristics:

1) 73% of the respondents reported their units were supported by surface mounted wood block foundations with timber pile as a second choice (14%).

2) Foundations support the mobile home with the floor level 600mm to 1000mm above ground in 70% of the respondents units.

3) All respondents reported their unit was skirted with 79% stating that the skirt was tight to the ground.

4) 79% responded that their foundations were not insulated.

5) 58% of the building inspectors reported that bases to support the mobile home were either not prepared or that they did not know if they were prepared to receive a mobile unit. 41% indicated that the bases were prepared.

6) The material used in the base was generally unknown (66%). Only 19% reported gravel as a base material. 67% of the inspectors reported that they did not know if the base was compacted.

7) In terms of the native soil, 28% of the inspectors reported that the bases were prepared while 58% reported no knowledge on the base. Of the bases that were known, 39% of the inspectors reported that they were stable.

8) Park managers reported that wood blocking was the most common type of foundation.

9) 56% of the building inspectors reported that wood blocking was a suitable foundation system for their area with 44% stating that the system was not suitable or that they did not know if it was suitable.

10) 61% of the park managers reported a preference for wood blocking with concrete pile as a second choice at 16%.

11) 54% of the park managers reporting indicate they level the foundations and follow-up once six months later. Of 22 park managers reporting, 60% indicate that the purchaser levels as required. A carpenter's level is the principle instrument used in levelling with shims being the main material and method to stabilize the levelness of the unit.

Orientation and Protection:

1) 87% of the homeowners indicated that the long side of their unit was oriented to face the North-west and west, the direction of the most prevalent winds in the Province.

2) The most prevalent wind directions in the Province were reported as the north-west and west (78%)

3) 74% of these units were protected by their neighbour's unit.

4) The average temperatures for mobile homes were 20 degrees C during the night and 22 degrees C during the day.

5) Approximately one third of the respondents stated that they experienced gentle rocking of their unit by the wind. No rough or violent rocking was reported, despite the fact that in certain areas of the Province winds of 60 kmph to 100 kmph have been recorded. Of the 4 respondents reporting damage by wind all state that it was damage due to flying objects such as roofing or decking from a neighbours unit. Hailstones also have been reported as the principal cause in damaging the siding and roof membranes.

6) Only 6 cases of damage were reported by park managers. This damage was generally as a result of material being lifted by the wind and impacting on the units.

Complaints:

1) 64% of the owners indicate that they had no trouble with doors jamming and 93% were not troubled by windows jamming.

2) Floor levelness in 83% of the units reporting were level and acceptable when the owners first moved into their home with 75% reporting that their floors were level at the time of answering the questionnaire.

3) The slope ranged from less than 6mm (1/4") to 32mm (1 1/4"). Only one person expressed the sentiment that he was upset with the floor of his unit sloping. His floor sloped 12mm (1/2").

4) 67% of the building inspectors did not receive any complaints. 31% of the building inspectors received only 1 to 5 complaints yearly about mobile home foundations.

5) Some building inspectors reported that the most troublesome foundation system appeared to be wood blocking. But others reported the least troublesome foundation system was wood blocking with concrete pile as close second at 21%.

6) 15% of the building inspectors reported mobile units which slid were supported by wood block foundations while 79% reported no sliding observed on wood block foundations.

7) Wind accounted for sliding in 3 cases while settlement is suggested as the cause of sliding in 4 cases. Poor anchorage was reported in 3 instances. Some 68% of the building inspectors reported that they had no knowledge of sliding or had not received any complaints on sliding.

8) Seven out of nine building inspectors report a high water table in their area of jurisdiction.

9) Most complaints came from parks located on clay, sandy-clay and silty clay soils (which are frost susceptible).

10) 74% of the park managers reported that ground water presented no problem. Approximately one quarter of the returns state foundations are troubled by ground water.

Foundation Costs:

1) The average cost of each wood block foundation is reported by park managers as $300.00, but the ranges reported are so wide as to reduce the reliability of the information.

2) Park managers reported concrete pile costs ranged from $1000 to $2500.

8.0 Assessments and Conclusions

8.1 Introduction

The purpose of the study was to investigate characteristics of major mobile home foundation systems in order to help establish design criteria for such foundations. In its early stages, the study indicated that surface mounted wood blocking was the dominant foundation system used and the study was therefore focussed on this type of foundation.

As explained, the study included surveys of experience with and field monitoring of mobile home foundations. Because of the mildness of the winter during which the field monitoring was carried out, some conclusions on appropriate design criteria had to be drawn from current practice and field observations.

One significant conclusion of this study , is that design criteria vary with the type of study information gathered and received. The results of the survey of experience and opinion suggest different limits of foundation movement due to frost heave than the field monitoring results, which , in turn, suggest somewhat different criteria than acceptable practice for most structures. Furthermore, the survey results were not statistically representative and indicate a wide range of opinions on the performance and adequacy of wood block foundations.

It is against this background which conclusions and recommendations have been formulated.

8.2 Assessment and Conclusions

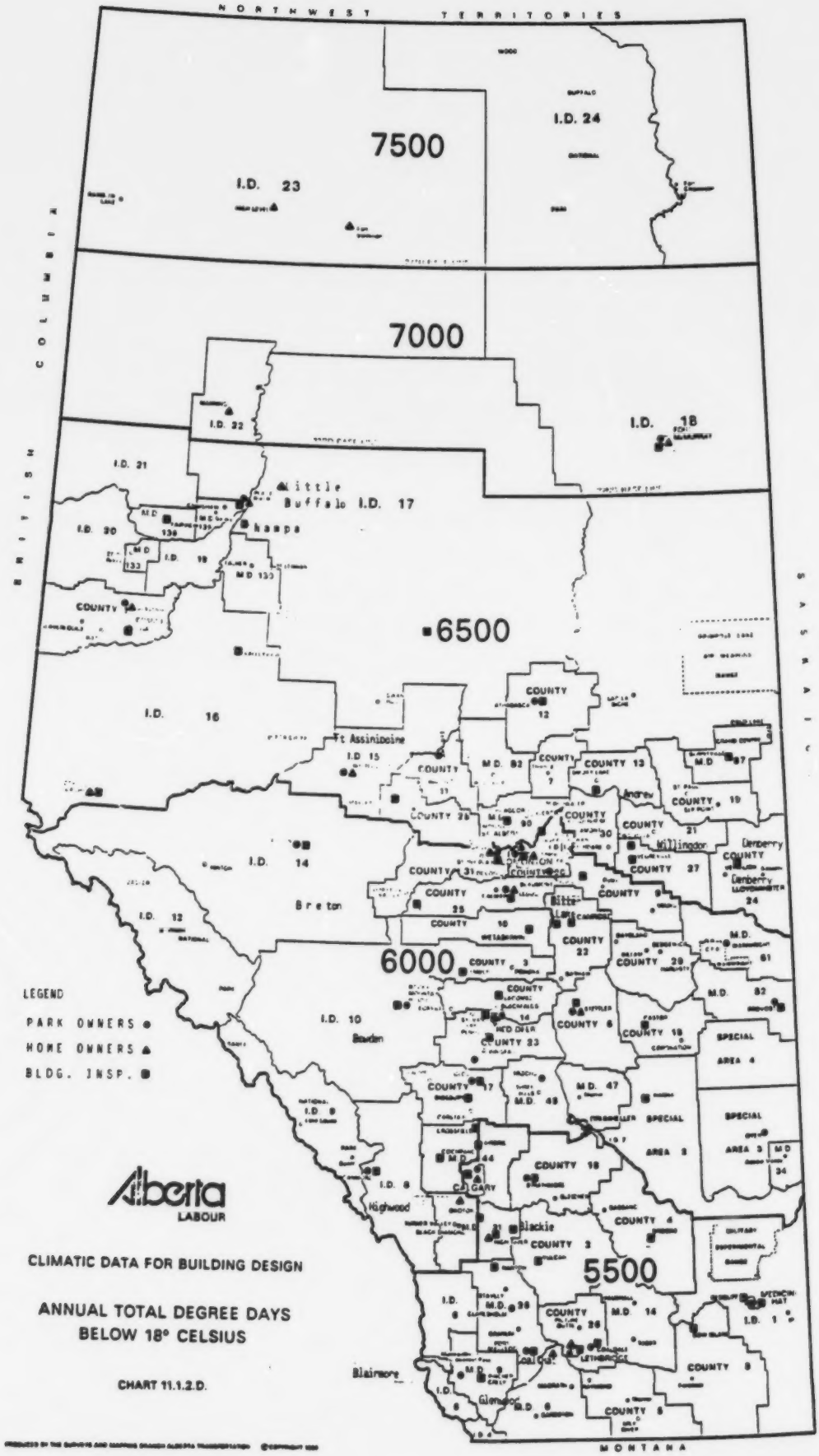
8.2.1 Performance Considerations

It is significant to note that over half of the returns were submitted by homeowners who have lived in mobile homes more than three years. Their responses are judged to be tempered with experience and treated as being meaningful.

The geographical coverage obtained in the questionnaires returned was extensive. This is clearly shown on page 62 in chart 11.1.2D of the Province of Alberta. Coverage of this magnitude provides a reasonable cross section of the founding soils and their influence on foundations have been noted by the respondents. However, there was very little information given on the type of base material used or whether or not the native soil and base soil was prepared and compacted.

Returns indicated that much of the Province is comprised of clay, sandy-clay, and silty clay. These categories of soil are potentially frost susceptible if freezing temperatures and water are present to cause and sustain the freeze thaw action.

Complaints received about foundations settling, constitute one third of the responses. Causes given for settlement were a poorly constructed base, high ground water levels, placement of units on black soil, poor anchorage systems and sliding due to wind.


NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
MONTANA
7500
7000
6500
6000
5500
I.D. 24
I.D. 23
I.D. 22
I.D. 18
I.D. 21
I.D. 17
I.D. 20
I.D. 19
I.D. 16
I.D. 15
I.D. 14
I.D. 12
I.D. 10
I.D. 8
I.D. 1
Little Buffalo
Hanna
Ft Assiniboine
Breton
Bowden
Highwood
Blackie
Blairmore
Glenwood
Willingdon
Andrew
Derberry
Calgary
Coal Cut
Lethbridge
LEGEND
PARK OWNERS
HOME OWNERS
BLDG. INSP.
Alberta
LABOUR
CLIMATIC DATA FOR BUILDING DESIGN
ANNUAL TOTAL DEGREE DAYS
BELOW 18° CELSIUS
CHART 11.1.2.D.

There were disparities in the acceptability of wood blocking as a foundation system. Hardy Associates had qualifications in its use with a strong preference for concrete pile foundation.

Consumer and park manager acceptance of the use of wood blocking as a foundation system was very strong. No major complaint was reported in its use. The few reported rejections of wood blocking were always attributed to an unacceptable soil condition or wind action.

8.2.2 Field Consideration.

Results from the monitored units at Edmonton, Red Deer, Calgary and Lethbridge provided little information on frost heaving due to the mild winter. The only frost penetration of consequence ocurred at Fort McMurray.

The monitored unit at Fort McMurray was set on its foundation in the Fall of 1983. Wood blocking served to support the mobile unit over a prepared pad of fill material. Blocking was levelled by the mover initially. An uninsulated skirt surrounded the unit and was fitted down to the soil surface. It is typical of most mobile unit installations in the the Province of Alberta and therefore its reaction to environmental changes should be representative of other units in a similar situation.

Frost penetration at Fort mcMurray reached a recorded depth of 2.6 metres by April 5th, 1984. This depth is approximately equal to the maximum depth that can reasonably be anticipated one year in twenty five for a soil type of sand gravel.(Reference Hardy Plate A.8)

Heave due to lense growth at Fort McMurray was approximately 75mm. The floor sloped as a result of the heave approximately 13.5mm in 3 metres. (An angular distortion of 1:222). This slope did not cause structural damage and was considered by the owner to be only a nuisance.

It would appear from the investigation of the Fort McMurray unit that the principal problem with surface mounted foundation systems was due to the differential movements experienced as a result of the variations in the thermal gradients in the soil. The differential movements experienced due to ice heave were not structurally critical.

Survey findings also indicate slopes up to 38mm in 3 meters were tolerated. This equates to an angular distortion of 1:80.

8.2.3 Structural Consideration

Surveys of the wood blocking supporting mobile homes indicate that they are rather variable in their configuration and structural integrity. Blocking was generally found to be toe nailed together and structurally not well integrated. Materials ranged from a stud type blocking to railroad ties. Nonetheless, most survey results indicate that the wood block foundation system is reasonably trouble free, and is easily maintainable and replaceable by the owner.

If placed on a well prepared base at the sub-soil level and constructed carefully, wood blocking could be used in many areas of the Province and on subsoils of reasonable quality.

It is concluded that no structural damage or serious damage to the interior finish, partitions or panel walls would occur in mobile homes at angular distortions smaller than 1:300.

8.2.4 Liveability Consideration.

There appears to be a recognition among mobile home owners that foundation movement is to be expected and its consequences tolerated and/or remedied by relevelling the unit.

In a discussion with the owner of the monitored unit at Fort McMurray it was learned that small cracks had appeared in the wall paper and sliding doors had jammed, but both were tolerated.

Findings seem to indicate that it may sometimes be economical to allow vertical movement to an extent where some minor damage of a cosmetic nature occurs and to repair afterwards. If this is accepted, the limiting angular distortion in terms of differential movement could be set at 1:300.

If this concept is not acceptable, it would be necessary to use foundations systems that will be installed at depths greater than those shown on the drawings 1 to 6 or at least below the zone of seasonal change.

8.3 Assessment of Foundation Cost.

Satisfactory information was not obtained to estimate the costs of the traditional surface wood blocking reliably. Responses to this part of the questionaire were very poorly answered. Those costs reported ranged from zero dollars (use of whatever wood was handy) to $850.00. An average figure of those reported is $300.00 for surface mounted wood block systems. Reported costs for concrete pile also varied widely and were not reliable.

An estimate of foundation costs is very much a factor of the locality and availability of qualified manpower and equipment.

8.4 Assessment of Insulated and Non-Insulated Skirting.

Virtually all mobile homes are skirted in Alberta according to the survey. 80% of these units have uninsulated skirts.

In most instances, the crawl space and uninsulated skirt was not heated. This will have little influence on the degree of frost penetration.

The National Research Council's study on basement heat loss prepared by G.P. Mitalas, and C.M.H.C.'s paper on the comparison of heat loss techniques, prepared by Michael Toemayne, indicate the value of insulated skirting on a mobile home is indeterminate. The subject requires more indepth study to provide useful factual information, but it is evident from both papers that a heated crawl space will reduce the penetration of the frost front immediately below the mobile home. However the cost in energy to obtain a frost free soil and at the same time maintain adequate ventilation may well be prohibitive. In addition a heated crawl space may dry out the soil which may expose the mobile home to increased settlement.

The conclusion then, is that uninsulated skirting around mobile homes is the best method of enclosing the space around units for the reasons cited.

9.0 Recommendations.

1. The preferred foundation system is a professionally designed and properly constructed surface mounted or sub-surface system installed on non frost susceptible soil.

2. Foundations systems may be used in frost susceptible soils subject to the following criteria:-

i) an informative geotechnical soil report on prospective park sites be obtained which assesses the potential of frost heave;

ii) that the foundation system be designed in accordance with the geotechnical information to limit movement to be no greater than a differential movement to give an angular distortion of 1:300; and

iii) that all units be securely anchored to the foundation system selected to prevent separation when the unit is stressed by external forces such as wind.

iv) that surface mounted foundation systems:-

a) be placed on well prepared and compacted in-situ soil.

b) be placed on well prepared and compacted base to C.S.A. standards

c) be securely anchored to the frame of the mobile home unit.

d) be designed so that individual blocks act as a single unit.

3. Units constructed with insulated skirting and a heated crawl space must be designed to ventilate the crawl space below the unit adequately to prevent condensation.

4. Units constructed with non-insulated skirts must also provide adequate ventilation of the crawl space.

APPENDIX A

HARDY AND ASSOCIATES 1978 LTD.

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

PERMANENT FOUNDATIONS FOR MANUFACTURED HOMES

ALBERTA DEPARTMENT OF HOUSING

EG-05830 JUNE 4, 1984

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

EG-05830

June 7, 1984

J. M. Mulligan and Associates Ltd.
10308 - 121 Street
EDMONTON, Alberta
T5N 1K8

ATTENTION: Mr. John Mulligan, P.Eng.

Dear Sirs:

Re: Frost Heave Studies
Manufactured Home Sites
Alberta Department of Housing

Enclosed are six copies of our report on the geotechnical aspects of the above study. As pointed out in the report, the winter of 1983/84 was unusally mild with the result that the only site with significant depths of frost penetration and amounts of frost heave was at Fort McMurray. We have suggested in the report that the thermistor strings be left in place, wherever possible, and further readings of frost penetration and heave be taken next winter.

The recommendations in our report are based mainly on our previous experience with frost penetration and heave, published information from other agencies and work we have carried out for other clients. The most popular type of foundation for manufactured homes in this country is wood blocks placed on the ground surface. In our experience, such a foundation type is only suitable where the possibility of frost heaving is extremely remote. Such sites are normally restricted to well drained gravel terraces. None of the sites mentioned in this study are in this category.

For most locations in Alberta, we suggest that strip footings, placed below the depth of frost penetration, would be the most suitable and economical type of foundation. Such foundations can be installed by small contractors. In some circumstances, particularly at locations in or close to major cities, cast-in-place concrete piles would probably be more economical. Driven piles form a suitable foundation for manufactured homes only in exceptional circumstances.

We are planning to take one more set of readings about the 15th of June. The results will be forwarded as an addendum to this report.

.../2

We believe the report is self explanatory and deals with all the points in our terms of reference. Should you wish to discuss this report with us in more detail, we would be pleased to meet with you and representatives of Alberta Department of Housing at your mutual convenience.

Yours truly

HARDY ASSOCIATES (1978) LTD.

Per:

G. McCormick, P.Eng.
Geotechnical Division

GMcC/jh

Enclosures

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1.0 INTRODUCTION

At the request of Mr. John Mulligan, P.Eng. of J. M. Mulligan and Associates Ltd., acting on behalf of Alberta Department of Housing, Hardy Associates (1978) Ltd. undertook an investigation of frost penetration at five sites in Alberta.

The objectives of the study were to obtain parameters which could be used in preparing recommendations for the design of permanent foundations for manufactured homes under various conditions in this Province. The five sites selected were at Fort McMurray, Leduc, Red Deer, Calgary and Lethbridge. Details on each site, and the results obtained, are in Section 5.0 "Analyses of Program Results".

The work of Hardy Associates (1978) Ltd. was limited to studying the effects of frost action only. The influence of other factors was outside our terms of reference.

At each of the five sites, two thermistor strings were installed in the ground adjacent to the home. The spacing of the thermistor beads was nominally 300 mm with eight beads being placed in each string. The strings were placed in the ground with the depth to the top thermistor ranging from 150 to 460 mm. In each case, this depth was carefully measured. As the depth of frost penetration at Fort McMurray usually exceeds 2.1 m, a double string was placed in each hole at this site with the beads placed in the depth interval of 0.15 to 4.25 m. At the other four sites, the depth to the bottom thermistor was 2.1 m.

At frequent intervals, generally about every two weeks, the temperatures in the thermistor strings were read and the elevation of certain points on the home were measured and

referenced to a reliable benchmark. In some cases, a slotted plastic standpipe was installed in order to monitor the fluctuations in the groundwater elevations.

Prior to the commencement of the field work, published literature and our own files were reviewed for information on both the theoretical and actual depth of frost penetration found under various conditions.

2.0 FROST PENETRATION

At the end of the text is a list of references on such subjects as frost penetration, rate of thaw, frost heaving phenomena and related subjects. The references are numbered and where a reference is cited in the text the number is indicated in parentheses.

2.1 THEORETICAL STUDIES

The factors which influence the rate and depth of frost penetration have been understood for many years. These factors are: ground surface temperatures, time, soil density, soil type and soil water content.

The influence of ground surface temperature and time can be expressed using the concept of the freezing index. In the SI system the accumulated freezing index, at any date, is found by simply adding the negative values of the mean daily air temperature from the start of continuous sub-freezing temperatures to the particular date at which the depth of frost penetration is required. In general, this method is fairly straight forward in the greater part of Alberta since experience has shown that, once continuous sub-freezing air

temperatures have commenced, the influence of occasional days of above-freezing temperatures is of little significance. Where prolonged periods of above-freezing temperatures are found during the winter, such as southern Alberta, western Europe and the northeastern United States, the problem is more complex.

The freezing index at the ground surface is always less than the air freezing index so that a correction factor must be used, applied to the value of the air freezing index, where the ground surface temperature is not monitored on a continuous basis.

Kersten (12) studied the coefficient of thermal conductivity of various soils on behalf of the United States Corps of Engineers. These studies showed that soils can be divided into two main groups, fine grained (clays and silts) and coarse grained (sands and gravels). Within these two groups the variation in the thermal conductivity of soil is governed by the density and the water content. In the case of frozen soils, Kersten found that the relationship between the conductivity and water content was essentially a straight line for a given dry density. However, in the case of unfrozen soils the relationship did not follow a straight line. Plates A-1 and A-2 (Appendix A) show Kersten's results as given by Aldrich (1).

If the above factors can be determined, the theoretical depth of frost penetration can be found using the Modified Berggren equation. Because almost all the reference material was published using Imperial units, these units had been retained in this section but, as will be seen, a conversion to metric units is quite simple.

$$X = \lambda \sqrt{\frac{48KF}{1.43\,WD}} \qquad (1)$$

where:

X = depth of frost penetration in feet

λ = a dimensionless coefficient

K = thermal conductivity of frozen soil (BTU/ft/hr/deg.F)

F = surface freezing index (degree-days F.)

W = moisture content (%)

D = dry density of soil (pcf)

λ is a dimensionless coefficient which is a complex function of the temperature, the volumetric latent heat of the soil and the volumetric heat capacity of the soil. Sanger (31) has published a nomograph showing the relationship of the air freezing index, the water content of the soil and the lambda coefficient.

The surface freezing index can be estimated from the air freezing index by multiplying the latter by a factor which has been found to vary according to the type of surface, topographic position and latitude. Sanger has given a value of 0.9 for this factor while Moulton and Schaub (18) found that in West Virginia the factor varied between 0.5 and 0.7. These last two authors are also of the opinion that this ratio (called the n-factor) becomes larger as the severity of the winter increases. The writer has found that an n-factor of 0.8 is a reasonable value to use in the southern part of Canada and a factor of 0.9 is a reasonable one in more northerly areas.

Kersten (12) has shown that, for moisture contents in excess of 4 percent, the thermal conductivity of any soil can be expressed by the relationship

$$K = A + BW$$

where A and B are constants for a particular type of soil at a given density. Kersten has given values for A and B. Equation 1 can now be re-written as:

$$X \text{ (in)} = 12\lambda \sqrt{\frac{48\ (A+BW)\ nF_a}{1.43\ WD}} \qquad (2)$$

$$= 12\lambda\sqrt{n}\ \sqrt{\frac{48\ (A+BW)\ F_a}{1.43\ WD}} \qquad (3)$$

where:

X = depth of penetration of frost (inches)

F_a = air freezing index
Equation 3 can be re-written in the form:

$$X \text{ (in)} = 12\ \sqrt{\frac{48\ (A+BW)}{1.43\ WD}}\ \sqrt{F_a}\ \ \lambda\sqrt{n}$$

Values of $\lambda\sqrt{n}$ have been plotted on Plate A-3 using a value for n which varies with the Air Freezing Index and values for taken from Sanger (31).

The expression $12\sqrt{\frac{48\ (A+BW)}{1.43\ WD}}$ has been evaluated for a range of

soil types, water contents and dry densities, using the data of Kersten, and the values plotted on the two charts in Plate A-4. This expression has been termed the Frost Penetration Factor. If the Frost Penetration Factor for a soil type can

be reliably found, or estimated, and the probable or design freezing index is known, the probable depth of frost penetration can be found quite easily.

In choosing the design freezing index, it is necessary to choose some return period or recurrence interval and to estimate the most severe winter liable to occur within that period. The Corps of Engineers Method (13) is to use either the most severe winter of the previous ten years or the average of the three most severe winters in the previous 30 years. McCormick (15) found that in the Prairie Provinces of Canada for a return period of 25 years the design freezing index has the relationship:

$F_D = 0.8\ F_M + 1,850$ degree-days F

where:

F_D = the design freezing index

F_M = the mean freezing index

For locations in the Prairie Provinces, the map shown on Plate A-5 can be used to find the design freezing index (degree days C). This map shows the 25 year (4%) freezing index. For the 50 year freezing index, the value shown on this map should be increased by 150 and for the 100 year index, the value shown on the map should be increased by 300.

The procedure for estimating the probable depth of frost penetration, therefore, is as follows:

1. Obtain information as to the nature of the subgrade soils, their type, classification, density and moisture content.

2. Decide on some value of the design freezing index which is to be used.

3. Using the charts in Plate A-4, according to the soil type, find the frost penetration factor and multiply this by the square root of the air freezing index.

4. Multiply agian by the factor $\lambda\sqrt{n}$ taken from Plate A-3.

The resulting value of frost penetration in inches can be used for design purposes where detailed local information on frost penetration is not available. The value obtained for frost penetration is based on the assumption that the ground surface will be clear of snow. If the snow cover is to be left undisturbed during the winter, local investigation as to the frost penetration beneath the snow cover at the end of a winter should be undertaken. To convert the depth of frost penetration to meters, simply divide by 40.

Values found by the above method have been compared with the actual depth of frost penetration beneath roads and runways and the correlation is excellent. The calculated depth of frost penetration using the above method has invariably been found to be conservative which is in accordance with the work of Jumikis (10) and Yong and Warkentin (40).

2.2 PUBLISHED DATA

The Construction Engineering and Architectural Branch of Transport Canada carried out a frost depth study program over the five winters of 1964/65 through to 1968/69. The study was carried out at approximately 30 civil and 8 military airports in various parts of Canada. At each airport, two Gandahl frost depth indicators were installed with one being placed in a paved area normally kept clear of snow and the second placed in an unpaved area where snow was allowed to accumulate. The Gandahl frost depth indicator consists of a plastic tube filled with a blue 0.05% xylene cyanol solution which becomes colorless below freezing point. The tube is installed in a plastic casing in the ground with the top protected by a screw cap. Reading the depth of frost penetration is extremely simple as it is only necessary to pull the tube from its casing and measure the length of colorless fluid.

In the Transport Canada study, readings were normally taken each week. In the case of the unpaved areas, the depth of snow was also recorded. Transport Canada has made available the data sheets on which are shown the date of each reading, the depth of frost, the depth of snow cover, (where applicable) and the soil profile.

By taking the temperature records for each airport, it is possible to correlate the depth of frost with the accumulated freezing index and we have carried through this exercise for a number of airports in Alberta. The values have been plotted on graphs and a number are included in this report in Appendix G.

Plate A-9 Appendix A, shows frost depths at various airports beneath uncleared areas. The insulating properties of a snow cover are well illustrated. In many cases, the snow is densified by wind action, often affected by the siting of buildings, so that the cover is much reduced and the frost penetration approaches the value for a cleared area.

The Atmospheric Environment Service of Environment Canada has soil temperature installations at many weather stations where the soil temperature profile is measured beneath an undisturbed snow cover. The data are published at quarterly intervals in Daily Soil Temperature Data. There are currently ten stations in Alberta reporting soil temperatures.

The Transport Canada study remains the most complete and thorough of any carried out in this country. Pare and Lavalee (22) have carried out some studies in earthen embankments in the James Bay Project.

3.0 FROST HEAVE

It as been recognized for almost 60 years that, under certain conditions, freezing soils will heave to a far greater extent than simple freezing of the pore water would indicate. The oldest reference on frost heaving is by Taber (34). Beskow (3) published another of the earlier studies as did Casagrande (5).

In the last 30 years, a considerable number of studies have been carried out on the precise mechanism causing frost heaving in soil. It is now recognized that for frost heaving to occur three conditions must be met: sub-freezing temperatures, a frost susceptible soil and a supply of water. If one of these factors is missing, or can be eliminated, frost heaving cannot occur.

Frost heaving beneath most buildings is eliminated by the flow of heat from the building passing through the soil and preventing sub-freezing temperatures occuring beneath the foundations. In some cases, such as manufactured homes and bunk-houses placed on wood-blocking, the building heat is not available to warm the ground and frost heaving often takes place. In other cases, heaving may occur because a basement, or below-grade parking structure, was not heated. In the case of some streets and roads, insulation has been used to prevent frost penetration beneath the pavement.

A frost susceptible soil is one in which the pores between the soil particles are small enough to permit capillary action, so that water will rise through the soil, but not so small that the soil is impermeable. Coarse sand and gravel is not subject to capillary action. Clay, or a soil which contains about 30% of clay-size particles, is usually sufficiently impermeable that capillary action cannot take place. It therefore follows that a frost suceptible soil usually contains a significant portion of material of silt-size so that a fine silty sand is invariably frost susceptible while a well graded dirty gravel may also fall within this classification. Many of the till soils in western Canada are frost susceptible because they contain insufficient proportions of clay-size material.

The factors causing soil to be frost susceptible have been discussed by a number of writers including Casagrande (5), Chamberlain (6), Csathy and Townsend (7), Linell and Kaplar (14) and Osler (21). Plate A-10 shows various frost susceptibility criteria.

The third component which is necessary for frost heaving to take place is a supply of water so that it is necessary for the water table to be sufficiently close to the ground surface, or other freezing plane, that ground water will rise by compillary action to feed the forming frost lenses.

The pressure exerted by freezing soils on the undersides of footings are quite large and have been measured as up to 200 kPa. In addition to simple frost heaving, frost jacking can also occur and considerable forces have been measured by Penner (23), (24), (25). The prevention of frost heaving and jacking in foundations is usually accomplished by placing the foundations to a depth below expected frost penetration, by heating the building or by insulation. In the case of straight shaft piles, frost jacking is usually avoided by placing the piles to a sufficient depth that normal soil friction or adhesion below the depth of frost penetration is sufficient to resist the frost jacking forces.

4.0 THAWING

The rate at which frozen ground will thaw, under a given set of conditions, is extremely difficult to calculate due to the many complex variables which influence the problem. Emperical methods based on actual field measurements appear to give the greatest promise for obtaining data of value for design and construction. Various authors, notably Scott (32) and Sanger (31) have explored the theoretical basis for depth of thaw calculations. Compared with the references which are available on the depth of frost penetration, published data on the depth and rate of thaw are meager. Charts showing the theoretical depth of thaw versus a given thawing index are reproduced as Plates A-6 and A-7 in Appendix A.

The factors which influence the rate of thaw at a given location include:

Infiltration by surface water
Thawing index
Wind Speed
Precipitation (rain and snow)
Vegetation
Organic cover
Surface color
Topography
Soil Type
Soil Density
Soil Water Content

It will be appreciated that the first four factors in the above list will vary from season to season although the variation will generally be within certain forecastable limits. The next three factors (vegetation, organic cover and surface color) can be varied by man's activities. The last four factors (topography, soil type, soil density and soil water content) will generally be fixed conditions within the life time of any engineering project although the water content of the soil may vary due to improvements, or otherwise, in drainage. The influence of water content and soil density is illustrated in Plates A-1 and A-2, Appendix A. Aldrich (1) has reported field data on depth of thaw for various airfield sites. Sanger(31) has shown how the wind speed can affect the surface thawing index.

Field data from the Transport Canada study give many examples of the rate of thaw for the various airport sites.

The rate of thaw has received little attention in the literature because, except for work in permafrost regions, the rate of thaw is of little interest in designing foundations or buried utility services. Transport Canada data from such sites as Whitehorse, where the airport is constructed on a gravel terrace, show that the rate of thaw in highly permeable soils is very rapid because the surface melt water carries heat to the subsurface and thereby accelerates the rate of thaw. In such circumstances, the air thawing index recorded to the time the seasonal frost has completely thawed is only a fraction of the air thawing index which would theoretically be required. However, at those sites where the soil is generally clay, and is relatively impermeable, the air thawing index recorded up to the time of completion of thawing is much closer to the theoretical value calculated from published methods. In general, the rate at which the ground thaws in the spring is of little practical interest to a designer for most locations in Alberta except for possible sites in the far north of the province. However, the rate of thaw may well be of vital concern to a contractor planning excavation work.

5.0 ANALYSES OF 1983/84 PROGRAM RESULTS

The winter of 1983/84 was unusually moderate in Alberta with the result that the usefulness of the data recorded is limited. At the three most southerly locations (Lethbridge, Calgary and Red Deer) the depth of frost penetration recorded was so small as to have little value. Even the site at Leduc, where a mean depth of frost penetration of 1.8 meters is exceeded on a 50% basis, the depth was very slight. Only at the Fort McMurray site was depth of frost penetration significant. It is at this last site that the only significant degree of frost heaving was found.

At Fort McMurray and Lethbridge, it was not possible to take elevations on the blocking because the owners objected to removal of the plywood skirting after first agreeing to the work being done. In these cases, points on the main frame had to be used.

All the manufactured homes surveyed were supported on wood blocks. The size and layout of the blocks are shown or noted in each case.

6.0 DISCUSSION AND RECOMMENDATIONS

The recommendations and remarks in this section are tentative and subject to review as more data becomes available. There are several types of permanent foundation which could be used for manufactured homes in Alberta. The system almost invariably used is wood blocking resting either on the ground surface or a gravel pad. Provided the foundation soils are not frost susceptible, the wood block system should function adequately for many years. In many cases, particularly where the soil is fine grained and there is a high water table, such a system often permits heaving in the winter. Re-levelling and shimming is often necessary in the spring and winter. In some cases, such as where the site is on a terrace of well-drained gravel, such foundations have performed equally as well as deeper foundations of concrete. Unfortunately, sites suitable for surface timber blocking are the exception in most parts of Alberta.

Based on the information available at time of writing, other types of foundation should be considered for some sites. At most sites where the foundation soils are clay, cast-in-place straight shaft concrete piles should be considered. Where the foundation soils are sand or gravel, strip or spread footings would probably be the choice. Where soft soils combined with a high water table are common, some type of driven pile may be necessary but, fortunately, such areas are not extensive in Alberta. The foregoing types of foundations are commonly used for small buildings where a full basement is not considered necessary or desirable. Two important points should be borne in mind when designing permanent foundations for manufactured homes: the crawl space beneath the trailer is seldom, or never, heated to normal room temperatures and it may be desirable to design the foundation so that it can be used by any model of home and not restricted to one particular design.

As the heat from the home cannot be relied upon to protect the ground beneath from freezing, foundations should be designed on the assumption that frost penetration may occur beneath the structure and the degree to which the ground temperatures will be ameliorated by building heat cannot be reliably estimated. At many locations, the possibility of swelling clay existing at the site should not be overlooked.

Preparing design parameters for each individual site is unlikely to be a viable procedure although such a procedure may be economical for sites developed in the future where a number of permanent foundations may be significant. We are therefore preparing recommendations for foundations based on only two main groups of soils with the depth of the foundation varying according to location in the province.

6.1 TREATED TIMBER BLOCKING

As mentioned above, pressure-treated timber blocks should perform adequately provided that the foundation soils consist of well-drained sand or gravel with a low water table. (A low water table can be defined as one where the depth to the winter water table is at least 1.5 m plus the depth of frost penetration). The timber pads should not be placed on topsoil. The topsoil should be stripped and replaced with a layer of compacted gravel. Allowable bearing pressures on gravel are high. A typical value is 300 kPa.

6.3 CONCRETE PILES

Straight shaft cast-in-place concrete piles form an economical foundation system for relatively light loads for the majority of building sites in Alberta. Such piles are installed by specialist contractors most of whom are based in Edmonton, Calgary or Red Deer. The equipment is mounted on a standard truck chassis so that mobilizing to smaller centres is economical. Normally, such equipment requires a two-man crew.

The design of such piles is usually based on the adhesion between the concrete and the soils with the parameter varying according to the shear strength of the soil. Typically, the concrete/soil adhesion (commonly referred to as shaft friction) ranges from 15 kPa in soft clay, to 100 kPa in shale or sandstone bedrock. It is considered good practice to assume that the top 1.5 m of shaft does not contribute to the load-carrying capacity of a straight shaft pile. The basis of this assumption is that clay may shrink near the surface due to the lowering of the water content or shrinkage due to frost action but the effects of such shrinkage will seldom exceed a greater depth than 1.5 meters.

Where straight shaft piles are subjected to frost action, which may occur in the case of such isolated structures as power poles, street lights or piles supporting isolated industrial equipment, there is a danger of "frost jacking". In such cases the ground may heave due to frost action and thereby lift or jack the pile. Penner (24 and 29) measured the adfreezing forces of clay on buried columns and reported adfreezing values of up to 180 kPa.

Such adfreezing forces can be resisted by the length of pile shaft below the depth of frost penetration. If the length of shaft below the depth of frost penetration is at least twice the length of shaft within the frost zone, frost jacking is extremely unlikely to occur. In cases where the clay is relatively soft, it may be necessary to increase the length of shaft to more than three times the expected depth of frost penetration. On the other hand, if bedrock is close to the surface, the length of shaft required to resist frost jacking is much reduced.

Isolating the pile concrete from the soil in the layer liable to freeze has been attempted in a few cases. Epoxy and polyethylene have been used. In general, attempting isolation of part of the pile shaft is seldom economical.

Belled cast-in-place concrete piles could be considered but their use would require an individual site investigation for a specific site where a number of permanent foundations are being considered. At one site, belled piles may be an economical alternative but for isolated cases the amount of engineering work required to design such piles would not be warranted.

6.3 STRIP AND SPREAD FOOTINGS

Strip footings would provide an economical foundation system at almost all possible sites in Alberta except for those which have been constructed over extremely soft ground. The main advantage of simple strip footings is that they can be installed by any small contractor using a backhoe or even, in some instances, hand labor. Neither installation nor inspection requires special equipment or personnel and the need to bring a specialist subcontractor into the work is eliminated.

It is essential that footings be placed beneath the depth of frost penetration and the possibility of frost jacking against the foundation wall or pedestal should also be addressed.

In most parts of Alberta, a footing placed at a depth of 2 meters below finished grade would be sufficiently deep to eliminate any possibility of frost action. In areas north of a line running through Lac La Biche and Valleyview, the depth of frost penetration which must be allowed for would be sufficiently great that the use of insulation to protect footings from frost action could be considered as also could isolating the foundation walls or pedestals from soil as described for piles. However, for standard designs, simplicity has many advantages and the use of more sophisticated methods should be restricted to those instances where engineering design and inspection is deemed economical.

6.4 DRIVEN PILES

Driven piles are a more expensive foundation system than cast-in-place concrete piles or traditional strip or spread footings. In many cases, the use of driven piles is inescapable but their use is normally a last resort for light structures. Timber piles are normally used. Until quite recently, Douglas Fir was almost invariably used in Alberta but Lodgepole Pine has been used with success in recent years. The cost of such piles, including installation and excluding mobilization charges, has been in the range of $60 to $70 per meter in recent years. The cost of mobilizing a rig and crew could range to $2 per kilometer, in both directions, with charges for crew subsistence also being added to the cost. Therefore, the use of driven pile foundations would only be economical in exceptional circumstances.

6.5 SUMMARY AND CLOSURE

In general, the use of the traditional timber block foundation for manufactured homes is completely acceptable at only a few sites in Alberta. While pressure-treated timber blocks will last for many years, experience has shown that such foundations are not satisfactory where the foundation soils are frost susceptible. Local experience with such a system is the best guide in judging its suitability for a given site.

The other systems mentioned have proven to be satisfactory. Strip footings placed below the depth of frost penetration will probably be the most economical choice in most areas. As they can be installed by small contractors, and do not require sophisticated engineering techniques for design, strip footings will be the indicated choice for most areas.

The design charts in Appendix A (Plates A-8 and A-9) are intended to be used where a site investigation is not warranted but some site supervision by an inspector or clerk of works can be assumed. These charts should not be used by a layman but are intended for use by persons with some experience in residental construction.

Because the winter of 1983/84 was unusually mild, the results to date of ground temperature and frost heave measurements are insufficient to serve as the basis for recommendations of foundation types. Therefore, reliance was placed on published information and material from our company files. It is suggested that the thermistor strings be left in place and further readings be taken next winter.

Respectfully submitted,

HARDY ASSOCIATES (1978) LTD.

PROFESSIONAL ENGINEERS ALBERTA

G. McCormick, P. Eng.

GMc/cm

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF ALBERTA
PERMIT NUMBER
P 226
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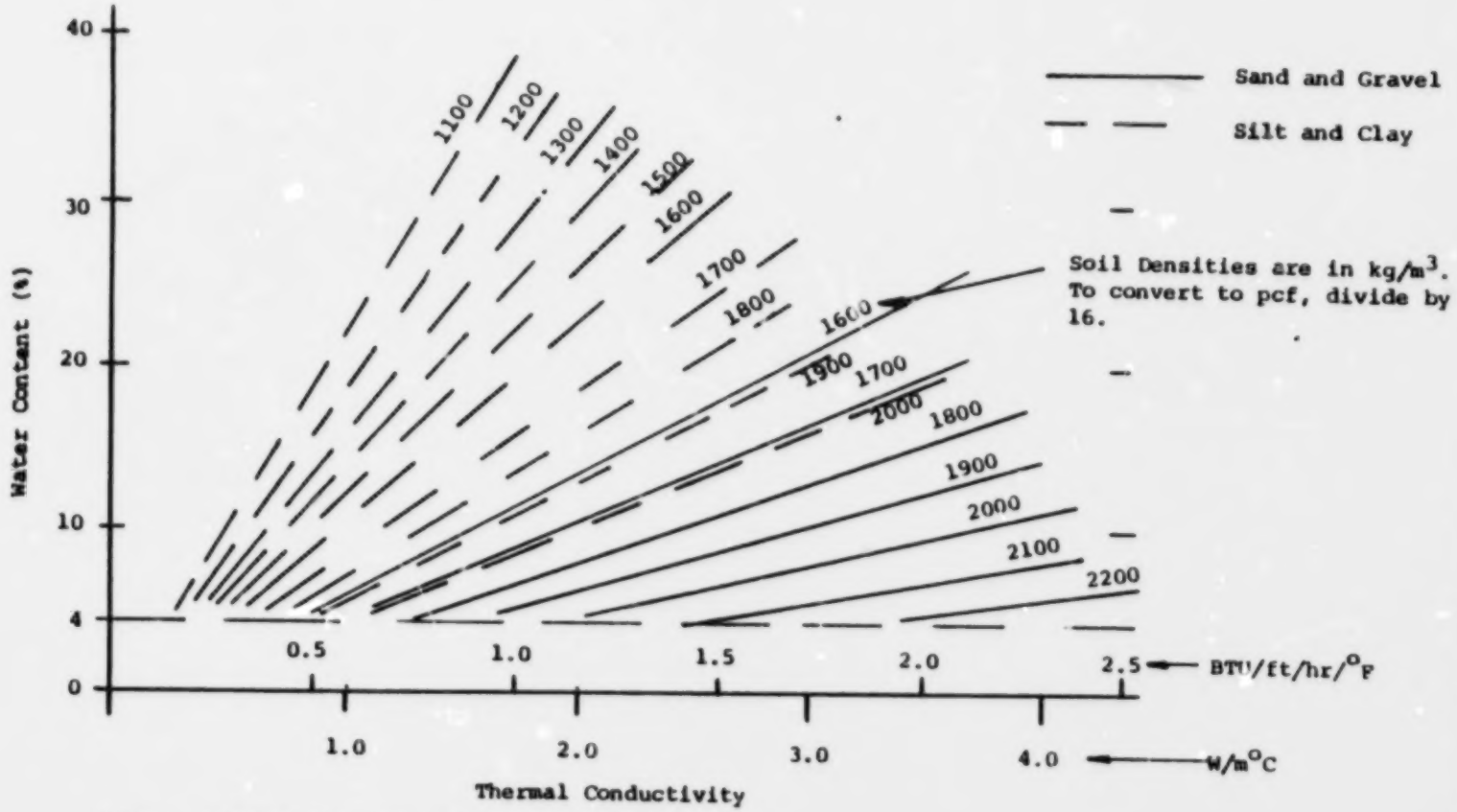
APPENDIX A

Charts
Maps

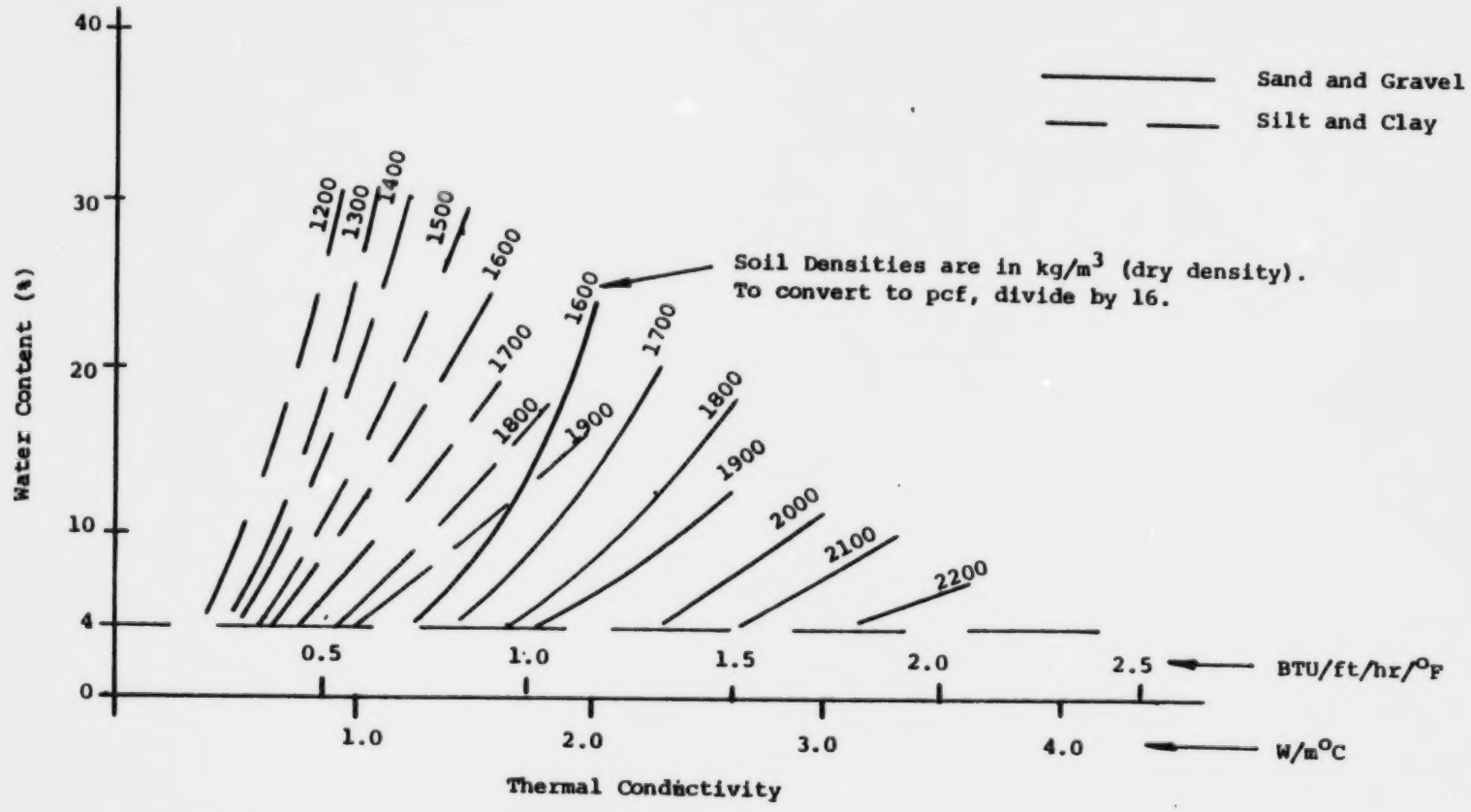


From: Aldrich H.P. "Frost Penetration Below Highway and Airfield Pavements" Highway Research Board Bulletin 135 (1956) pp 124-144.

HARDY ASSOCIATES (1978) LTD.

THERMAL CONDUCTIVITY
FROZEN SOIL

SCALE NA	DATE Mar 19/81	MADE G Mc	CHKD.	JOB: EG 5830	PLATE A-1



From: Aldrich H.P. "Frost Penetration Below Highway and Airfield Pavements" Highway Research Board Bulletin 135 (1956) pp 124-144.

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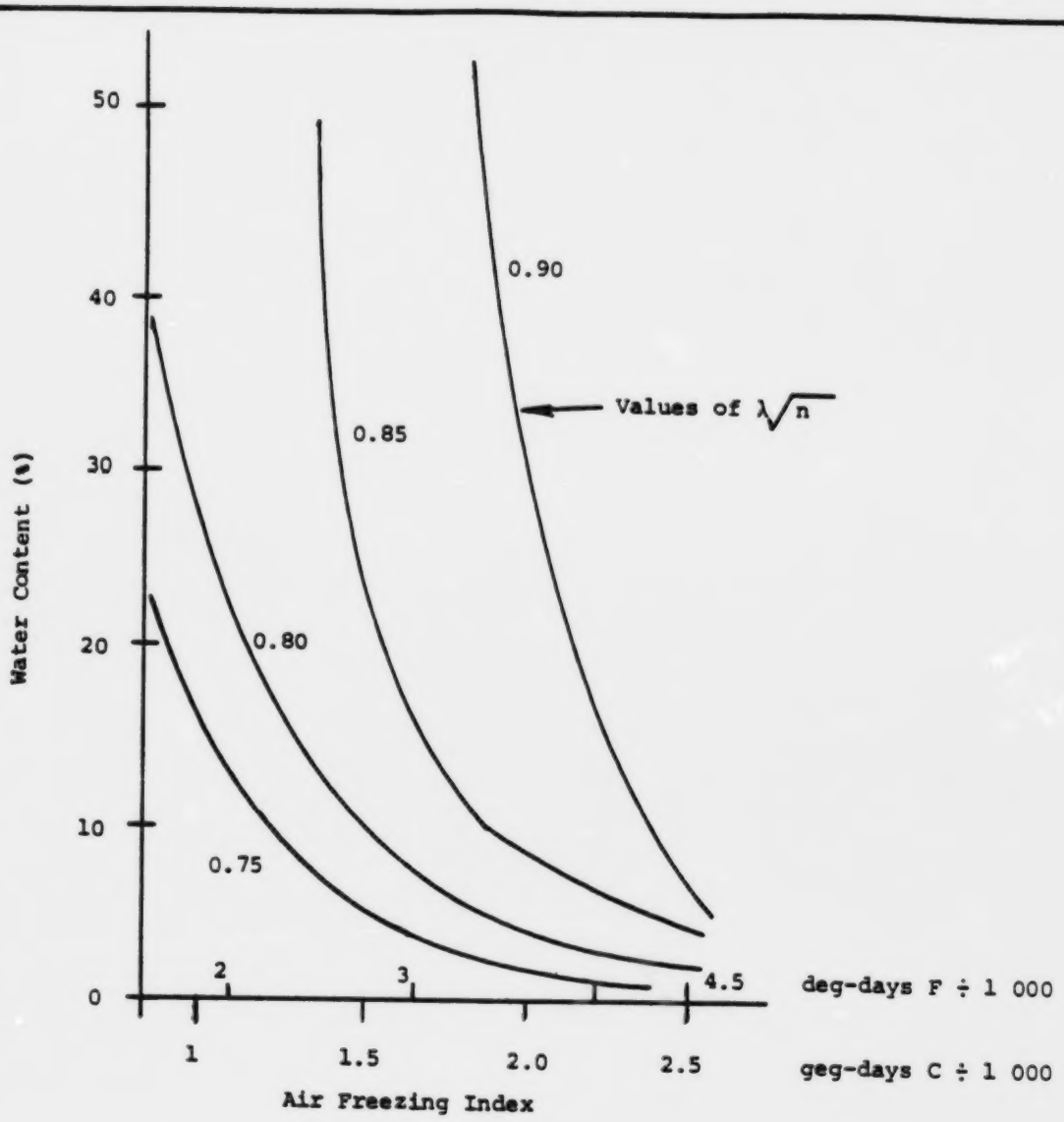
THERMAL CONDUCTIVITY
UNFROZEN SOIL

SCALE NA	DATE Mar 19/84	MADE G Mc	CHKD.	JOB: EG 5830	PLATE A-2

H212 79/05



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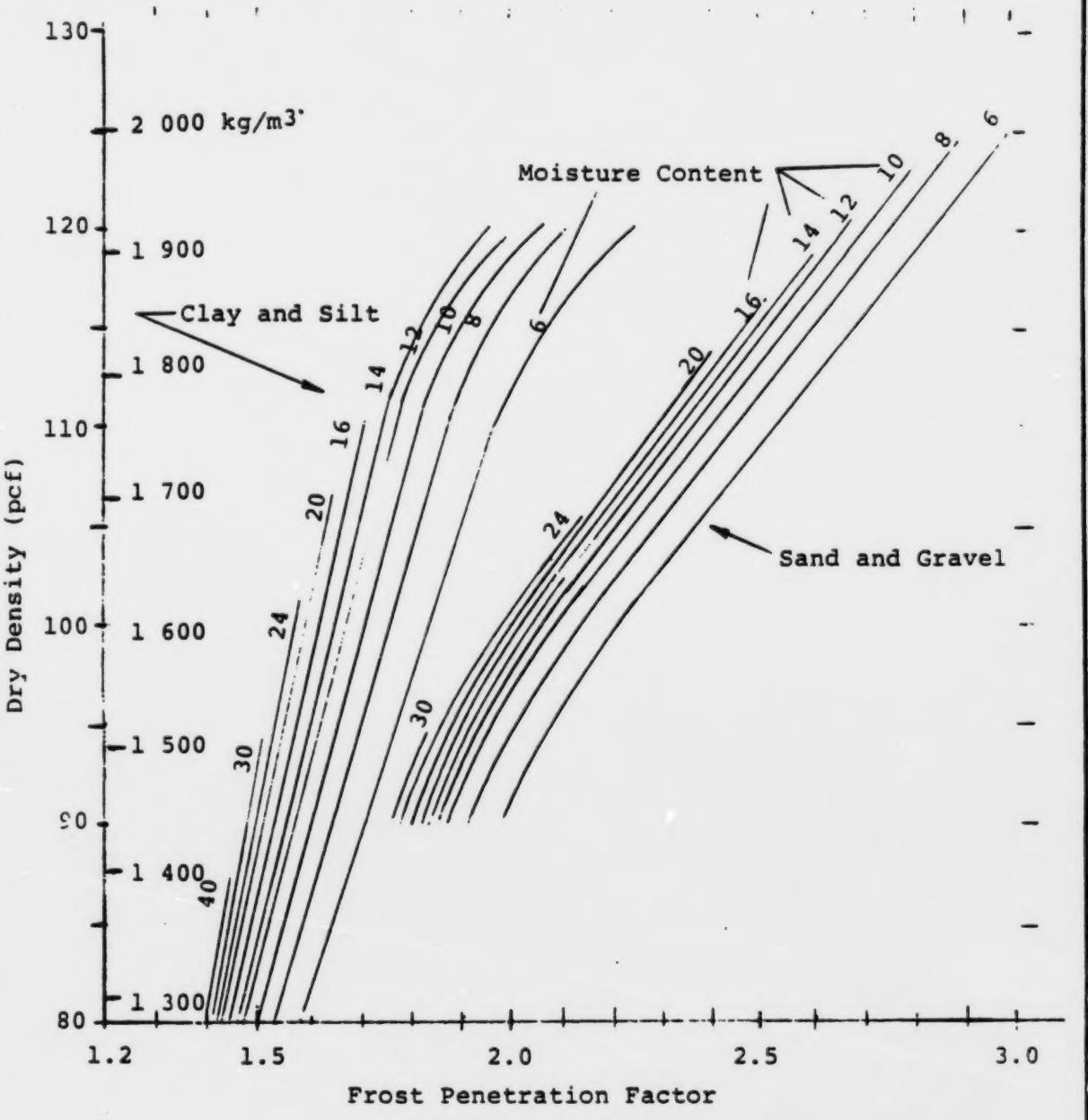
RELATIONSHIP OF AIR FREEZING INDEX
AND SOIL WATER CONTENT TO
λ AND SURFACE CORRECTION FACTOR

SCALE NA	DATE Mar 19/84	MADE G Mc	CHKD.	JOB: EG 5830	PLATE A-3

HT12 - 79 05

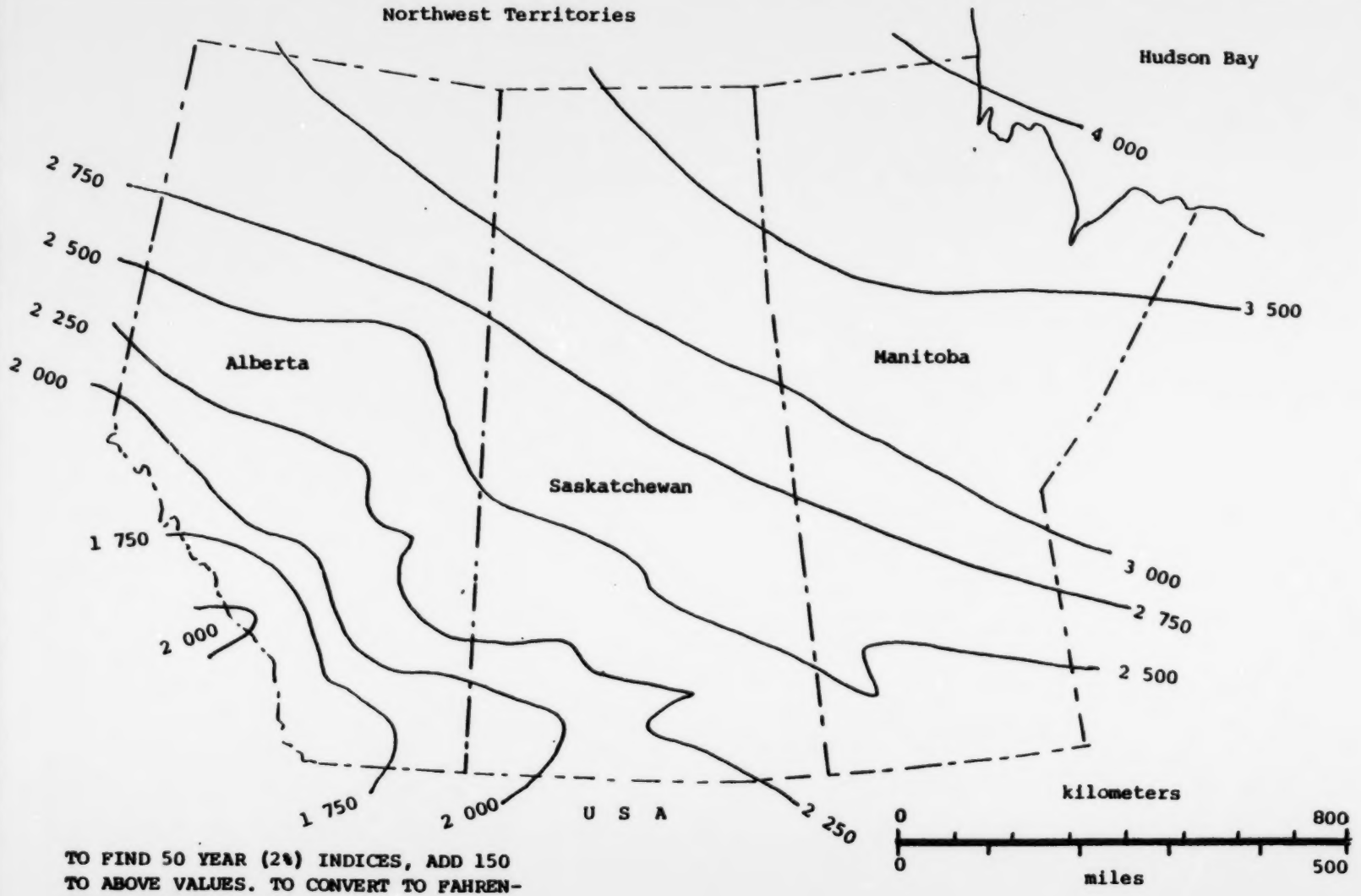


NOTE: TO CONVERT kg/m^3 TO pcf DIVIDE BY 16

R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

FROST PENETRATION FACTORS

SCALE	DATE	MADE	CHKD.	JOB:	PLATE A-4



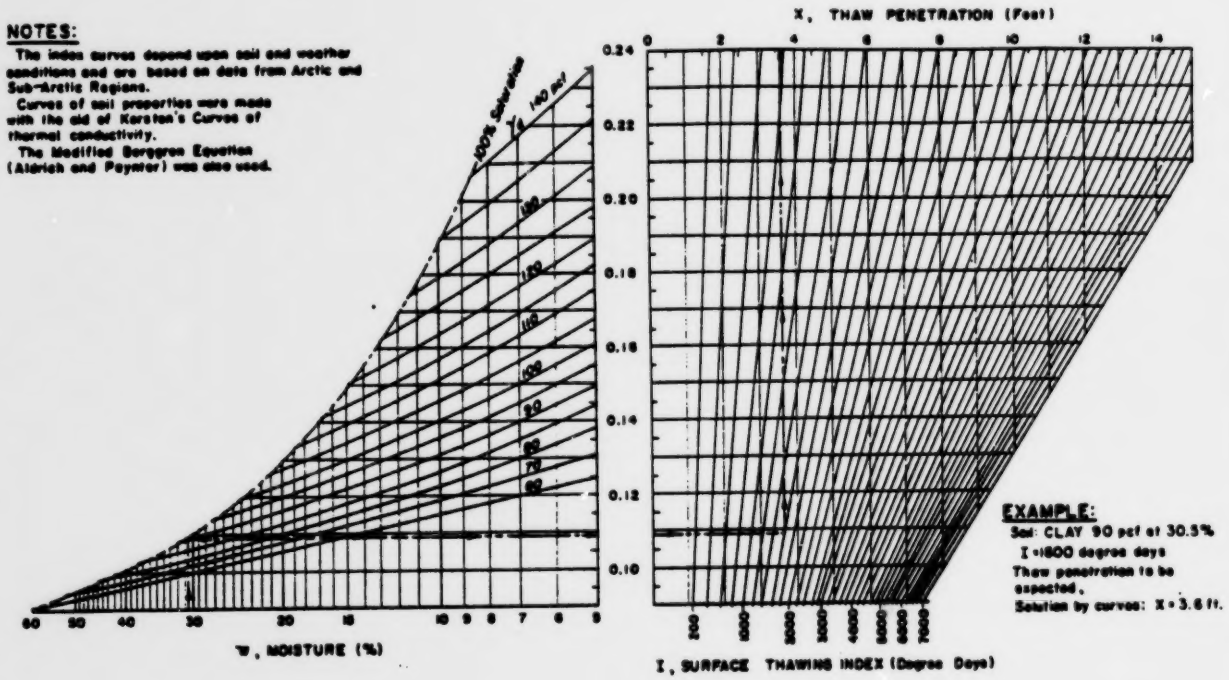
TO FIND 50 YEAR (2%) INDICES, ADD 150 TO ABOVE VALUES. TO CONVERT TO FAHRENHEIT, MULTIPLY BY 1.8.

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

DESIGN FREEZING INDICES
25 YEAR (4%) BASIS
DEGREE-DAYS CELSIUS

SCALE 1/10 mill	DATE Mar 19/84	MADE G Mc	CHKD.	JOB: EG 5830	PLATE A-5

HT13 79/05



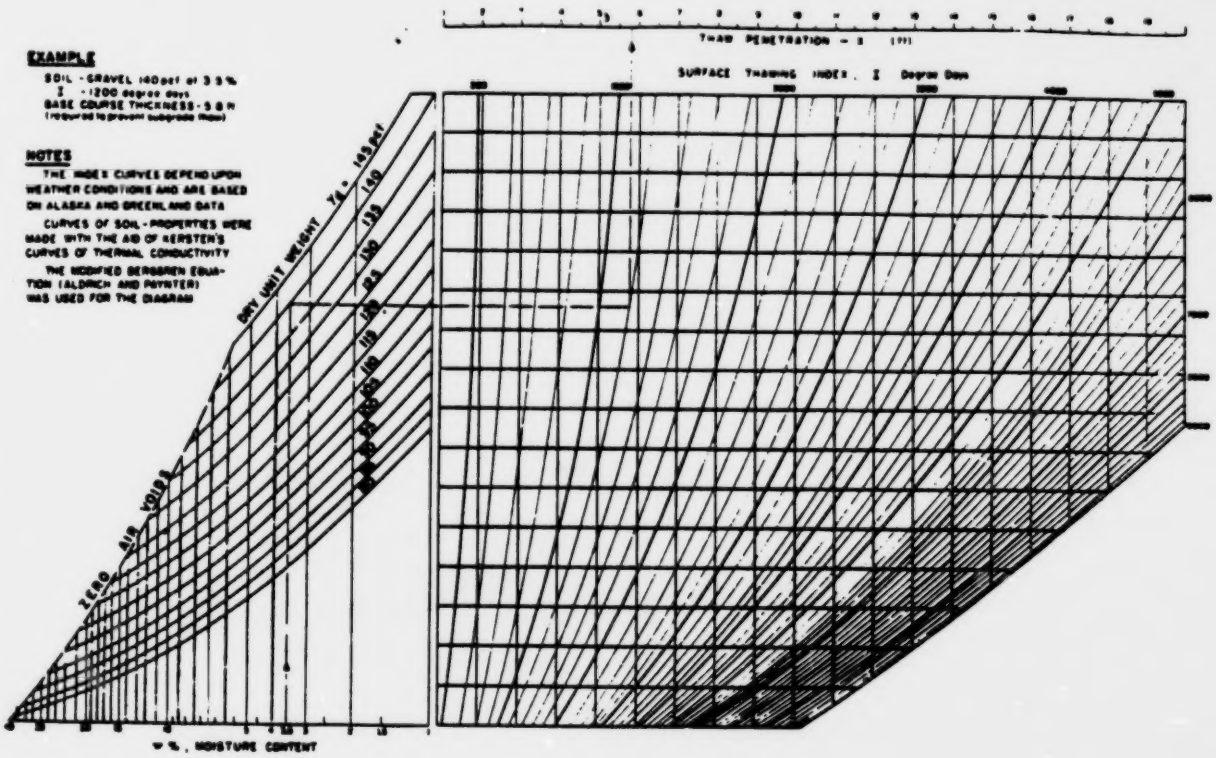
THEORETICAL PENETRATION OF 0°C ISOTHERM

FINE-GRAINED SOILS, THAWING

From: "Degree-days and Heat Conduction in Soils" by F J Sanger. First International Permafrost Conference 1963, Proceedings, page 258.

HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES			PENETRATION OF THAW PLANE FINE-GRAINED SOILS		
SCALE	DATE Mar 9/84	MADE G Mc	CHKD.	JOB: EG-5830	PLATE A-6

HT12 - 79/08



THEORETICAL PENETRATION OF 0°C ISOTHERM

COARSE-GRAINED SOILS, THAWING

From: "Degree-days and Heat Conduction in Soils" by F J Sanger. First International Permafrost Conference 1963, Proceedings, page 257.

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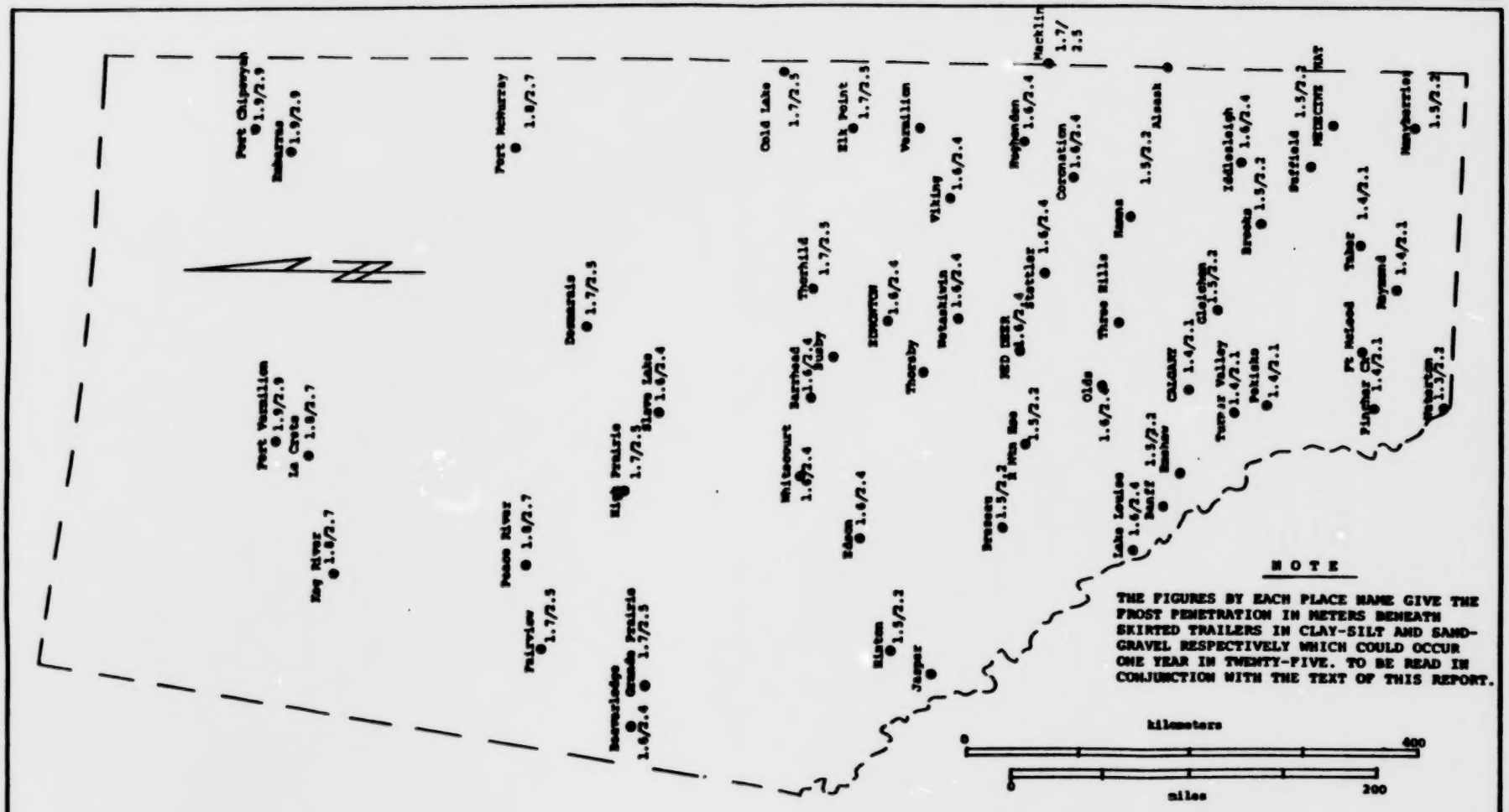
PENETRATION OF THAW PLANE
COARSE-GRAINED SOILS

SCALE	DATE Mar 9/84	MADE G Mc	CHKD.	JOB: EG-5830	PLATE A-7

HT12 - 79/05



NOTE

THE FIGURES BY EACH PLACE NAME GIVE THE FROST PENETRATION IN METERS BENEATH SKIRTED TRAILERS IN CLAY-SILT AND SAND-GRAVEL RESPECTIVELY WHICH COULD OCCUR ONE YEAR IN TWENTY-FIVE. TO BE READ IN CONJUNCTION WITH THE TEXT OF THIS REPORT.

REVISIONS	REFERENCES	SCALE 1/3,250,000 DATE Mar 7/84 MADE G Mc CHKD APPD	HARDY ASSOCIATES (1978) LTD.	FROST PENETRATION BENEATH SKIRTED TRAILERS 25 YEAR (4%) BASIS No. EG-05830 PLATE A-8

HT34 - 78/05

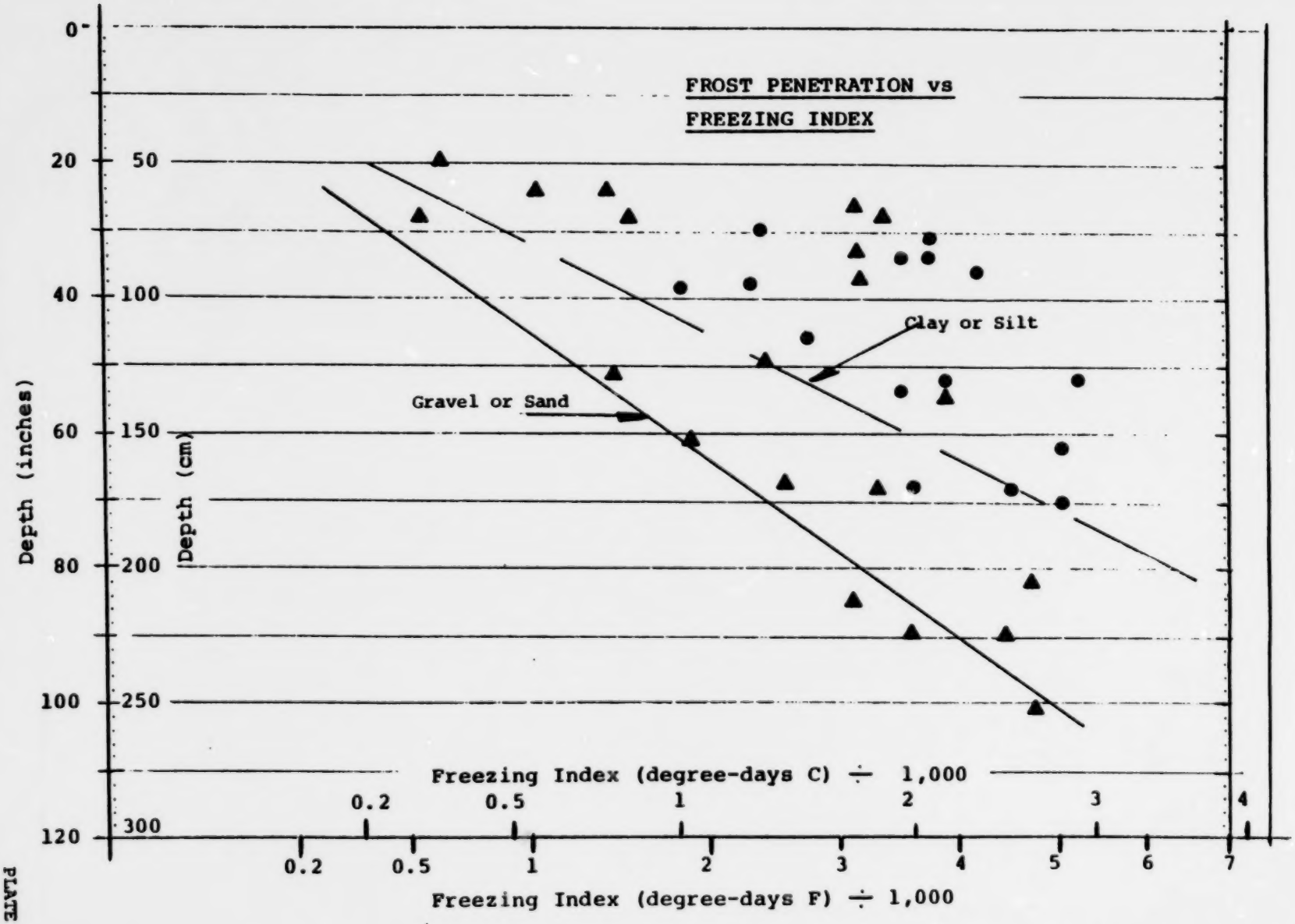
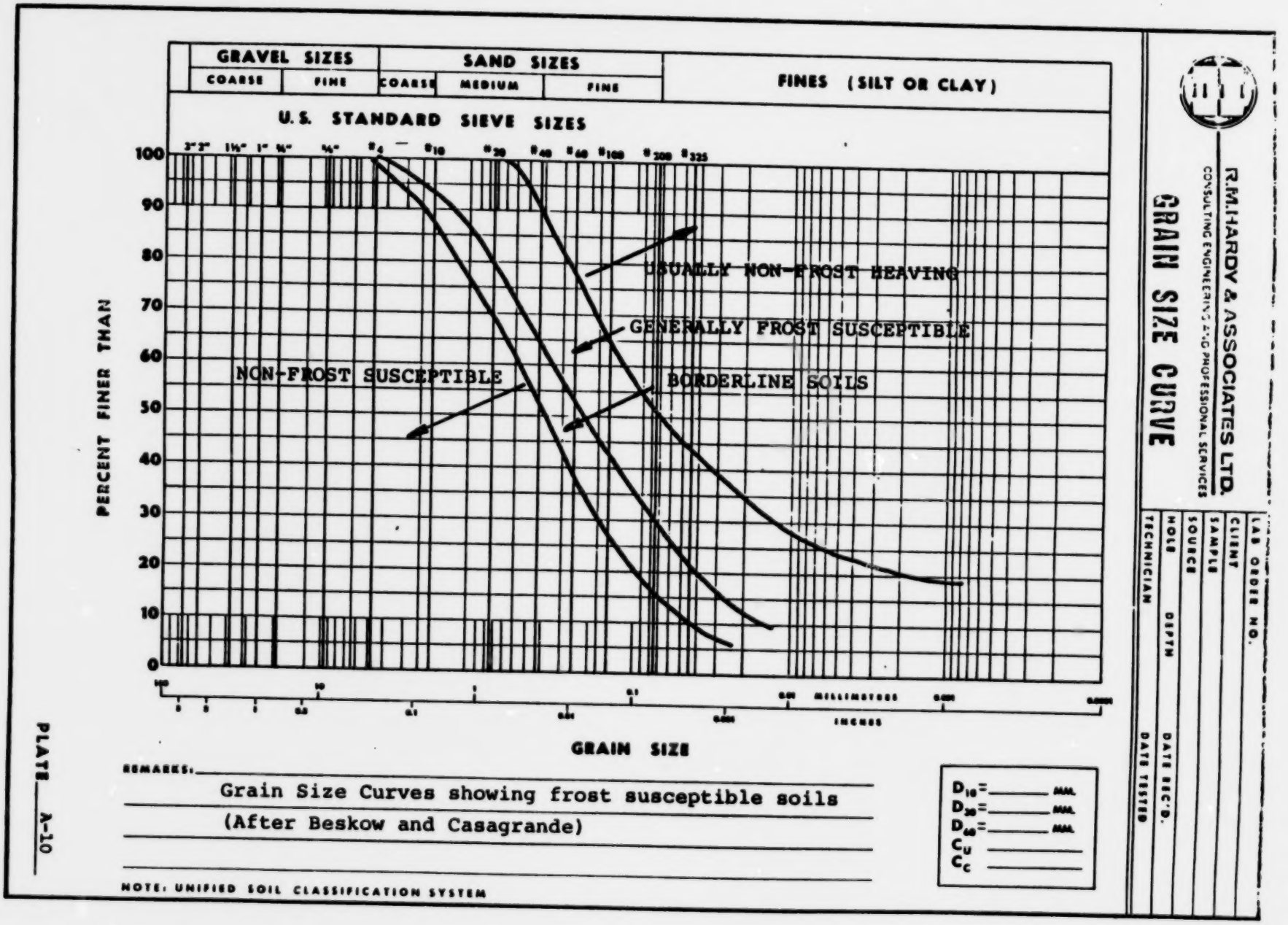


PLATE A-9

FROST PENETRATION BENEATH
SNOW COVER



REMARKS:

Grain Size Curves showing frost susceptible soils
(After Beskow and Casagrande)

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

D_{10} = _____ MM.
D_{30} = _____ MM.
D_{60} = _____ MM.
C_U _____
C_C _____

PLATE A-10

R.M. HARDY & ASSOCIATES LTD.
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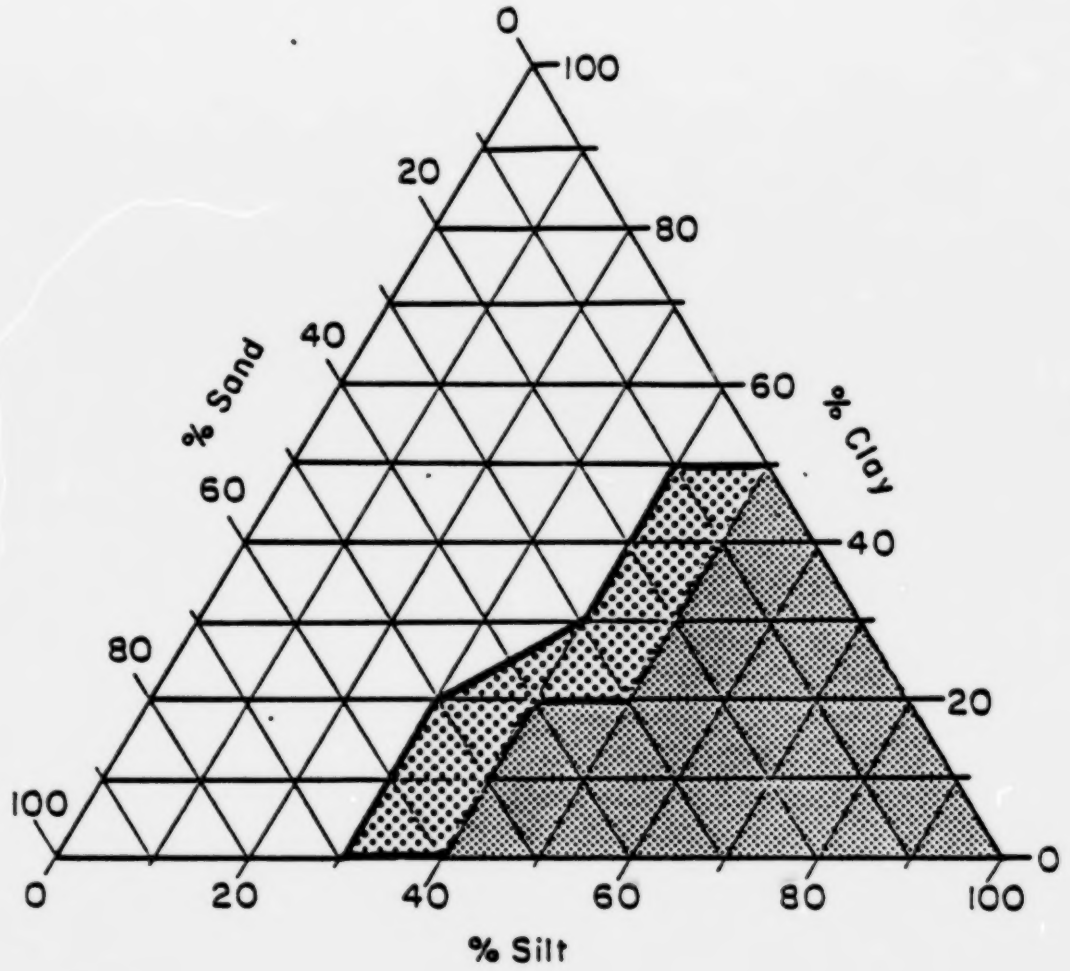
GRAIN SIZE CURVE

LAB ORDER NO.
CLIENT
SAMPLE
SOURCE
HOLE DEPTH DATE REC'D.
TECHNICIAN DATE TESTED



From: Chamberlain, E.J. et al "Identification and Classification of Frost Susceptible Soils" ASCE Spring Convention 1982 (Ref: 6)

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NEW BRUNSWICK
FROST SUSCEPTIBILITY CRITERIA

SCALE NTS	DATE Mar 8/84	MADE G Mc	CHKD.	JOB# 5830	PLATE A-11

HT12 - 79.05

APPENDIX B

Fort McMurray Results

FOOTING ELEVATION

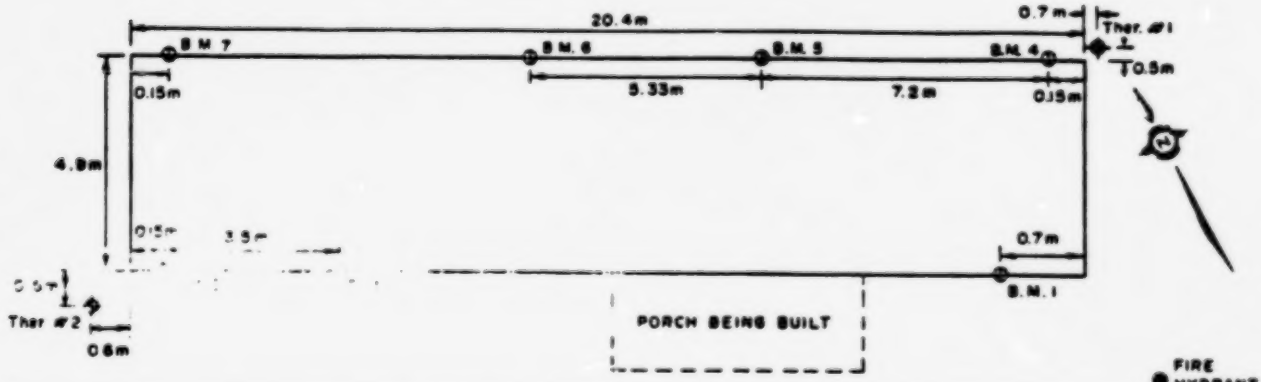
CLIENT: J. M. Mulligan & Associates Ltd.

PROJECT: Assessment of Manufactured Housing Foundation Systems

LOCATION: 140 Clausen, Lot 15, Blk. 26, Plan 8121566, Fort McMurray

BENCHMARK: Fire Hydrant, Elevation 360.462 m

PROJECT No.: EG-05830.1



B. M.	DATE / READINGS							
	Dec. 14/83	Jan. 10/84	Feb. 2/84	Feb. 17/84	Mar. 9/84	Apr. 5/84	May 1/84	Jun. 9/84
1	361.889	361.900	361.911	361.915	361.915	361.916	361.897	361.869
2	361.405	361.426	361.449	361.455	361.459	361.473	361.458	361.431
3	361.387	361.408	361.422	361.432	361.445	361.462	361.451	361.425
4	361.494	361.505	361.517	361.521	361.524	361.525	361.501	361.470
5	361.455	361.462	361.476	361.478	361.482	361.484	361.467	-
6	361.427	361.435	361.449	361.456	361.462	361.466	361.451	361.436
7	361.390	361.399	361.412	361.420	361.430	361.443	361.433	361.403
8								
9								
10								
11								

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT J.H. MULLIGAN & ASSOCIATES LTD.
ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEM - FORT MCMURRAY LOCATION

LOGGED/DWN BT/BT | CKD BT | DATE OF INVEST Dec. 9/83 | JOB NO EG-05830.1 | HOLE NO

WATER CONTENT — W_P - □ W - ○ W_L - △ — PERCENT % — 10 20 30 40 50 60

DEPTH m ft | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE | DRILL TYPE | OTHER TESTS

DATUM Fire Hydrant
Elevation 360.462 m
SURFACE ELEVATION 360.536 m

FILL,topsoil,clayey,black

FILL,sand and gravel,well graded, brown,75 mm max. size

FILL,clay,silty,some sand,stiff, medium plastic,pinkish-brown, clay till inclusions

Drill Type: Digger Mobile Portable Dri

Frost

End of hole at 4.0 m
(Hole drilled on angle)
Hole dry at completion
Installed two strings of thermistors
String #2 4.4 m
String #4 6.8 m
Backfilled with cuttings

PLATE 2

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT J.M. MULLIGAN & ASSOCIATES LTD.
ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEM - FORT MCMURRAY LOCATION

LOGGED/DWN.	CKD	DATE OF INVEST	JOB NO	HOLE NO
BT/BT	BT	Dec.12/83	EG-05830.1	2

DRILL TYPE: Digger Mobile Portable Drill

WATER CONTENT — w_P - □ w - ○ w_L - △ — PERCENT % — 10 20 30 40 50 60

DEPTH m	DEPTH ft.	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE: CONDITION	SOIL SAMPLE: TYPE	SOIL SAMPLE: PENETRATION RESISTANCE	OTHER TESTS
			DATUM Fire Hydrant Elevation 360.462 m SURFACE ELEVATION 360.541 m				
	1		FILL,topsoil,clayey,black				
	2		FILL,clay,silty,stiff to very stiff,medium plastic,pinkish-brown,high plastic pink clay lumps,odd cobbles to 100 mm diameter,clay till inclusions				Frost
1	3						
	4						
	5						
2	6						
	7		medium plasticity				
	8						
	9						
3	10						
	11		possible native clay,hard to distinguish from cuttings				
	12						
4	13						
	14						
	15		End of hole at 4.3 m (Hole drilled on angle) Hole dry at completion Installed two strings of thermistors String #1 4.4 m String #3 6.8 m Backfilled with cuttings				
	16						
5	17						

14°

4.1 4.3

1.0 m

PLATE 3

HT08 - 79/08

MOBILE HOME FOUN[illegible]TION

SURVEY
FOR
PROVINCIAL GOVERNMENT [illegible] ALBERTA
DEPARTMENT OF [illegible]NG
POLICY AND PLANNI[illegible]VISION

Thermistor 1

CONSULTANT: J.M. MULL[illegible] & ASSOCIATES LTD.
CONSU[illegible]G ENGINEERS

GEOTECHNICAL OFFICE: Fort [illegible]y

SURVEY DATA

MOBILE PARK: Cartier Mobile Home Park	LOT NO: Lot 15, Blk 26, Plan 8121566
ADDRESS: 140 Clausen Cresent	OWNER: Eugene Aube
PARK OWNER: Alberta Housing Corporation	MANAGER: Alberta Housing Corporation
DATUM: GEODESIC ELEVATION 360.462 m	LOCATION: Fire Hydrant in front of 140 Clausen Cresent
DATE PROBE INSERTED December 13, 1983 NUMBER OF THERMISTORS: 2 Strings of 8	DATE PROBE REMOVED:

TEMPERATURE READINGS

DATE		Depth (m)	0.46	0.76	1.07	1.37	1.68	1.82	2.00	2.13	2.30	2.45	2.60	2.75	3.05	3.35	3.65	4.00				
Dec. 15/83	LOCATION	1	-14	-4.5	-0.2	0.5	1.4	2.0	2.5	2.8	3.0	3.3	3.6	3.8	4.4	4.7	5.2	5.3				
Dec. 19/83	LOCATION	1	-15.2	-6.8	-2.0	0.1	1.1	1.6	2.1	2.4	2.3	3.0	3.3	3.5	4.0	4.4	4.8	5.0				

Fort McMurray Thickness

DATE:		Depth (m)	0.46	0.76	1.07	1.37	1.68	1.82	2.00	2.13	2.[illegible]	2.45	2.60	2.75	3.05	3.35	3.65	4.00				
Jan. 9/84	LOCATION	1	-14.8	-8.5	-4.1	-1.8	0.1	0.8	0.8	1.0	1.2	1.5	2.0	2.2	2.8	3.1	3.7	4.0				
Feb. 2/84	LOCATION	1	--	--	-3.7	-2.8	-1.5	-0.8	-0.1	0.2	[illegible]	0.8	1.0	1.2	1.9	2.1	2.8	3.0				
Feb. 17/84	LOCATION	1	-5.8	-4.5	-3.6	-2.8	-1.8	-1.2	-0.[illegible]	-0.3	[illegible]	0.5	0.5	0.7	1.4	1.8	1.9	2.2				
Mar. 9/84	LOCATION	1	-5.6	-4.8	-3.1	-2.2	-1.5	-1.1	-0.8	-0.5	-0.2	0.0	0.2	0.4	0.8	1.2	1.4	1.8				
Apr 5/84	LOCATION	1	3.6	-0.4	-1.0	-1.1	-1.1	-1.0	-0.8	-0.6	-0.4	-0.3	0.0	0.2	0.5	0.6	1.2	1.5				
May 1/84	LOCATION	1	6.5	3.4	1.5	-0.3	-0.4	-0.4	-0.4	-0.[illegible]	-0.[illegible]	0.0	-0.2	0.3	0.4	0.7	0.9	1.3				
June 9/84	LOCATION	1	16.[illegible]	8.3	5.8	3.7	1.9	0.9	0.1	-0.1	0.1	0.0	0.4	0.4	0.6	0.9	1.1	1.3				
Aug.24/84	LOCATION	1	18.2	17.9	15.9	14.9	13.3	12.8	12.2	11.5	11.1	10.4	10.2	9.8	9.2	8.2	8.6	7.2				
	LOCATION																					

MOBILE HOME FOUNDATION — Thermistor 2

SURVEY
FOR
PROVINCIAL GOVERNMENT OF ALBERTA
DEPARTMENT OF HOUSING
POLICY AND PLANNING DIVISION

CONSULTANT: J.M. MULLIGAN & ASSOCIATES LTD.
CONSULTING ENGINEERS

GEOTECHNICAL OFFICE: Fort McMurray

SURVEY DATA

MOBILE PARK: Cartier Mobile Home Park
ADDRESS: 140 Clausen Cresent
LEGAL NO: Lot 15, Blk 26, Plan 8121566
OWNER:
PARK OWNER: Alberta Housing Corporation
MANAGER: Alberta Housing Corporation
DATUM: GEODESIC ELEVATION 360.462 m
LOCATION: Fire Hydrant in front of 140 Clausen Cresent
DATE PROBE INSERTED Dec. 13/1983
NUMBER OF THERMISTORS: 2 Strings of 8
DATE PROBE REMOVED:

TEMPERATURE READINGS

DATE	Depth (m)		.15	.45	.76	1.07	1.37	1.68	2.00	2.13	2.30	2.44	2.75	3.05	3.35	3.66	4.00	4.25				
	LOCATION																					
Dec. 15/83		2	-12.5	-3.3	-0.1	1.2	2.0	2.6	3.2	3.6	4.0	4.0	4.4	4.5	4.8	5.2	5.3	5.2				
Dec 19/83	LOCATION	2	-13.3	-6.1	-1.8	0.4	1.4	2.2	2.8	3.2	3.4	3.6	4.0	4.4	4.6	4.9	5.0	5.0				

DATE: \ Depth (m)			.15	.45	.76	1.07	1.37	1.68	2.00	2.13		2.44	2.75	3.05	3.35	3.66	4.00	4.25
Jan 9/84	LOCATION	2	-11.2	-7.5	-4.6	-1.8	-0.7	0.6	1.1	1.6	1.[illegible]	2.1	2.8	3.1	3.5	3.9	4.1	4.1
Feb. 2/84	LOCATION	2	--	--	-3.7	-2.5	-1.4	-0.5	0.3	0.9	[illegible]	1.2	1.9	2.2	2.7	3.0	3.4	3.6
Feb. 17/84	LOCATION	2	-6.2	-4.8	-3.8	-2.6	-1.6	-0.6	0.2	0.5	[illegible]	1.0	1.8	1.9	2.2	2.7	2.8	2.9
Mar. 9/84	LOCATION	2	-7.3	-5.8	-3.9	-2.2	-1.5	-0.7	-0.2	0.5	[illegible]	0.8	1.2	1.5	1.9	2.1	2.7	2.8
Apr. 5/84	LOCATION	2	-0.3	-1.3	-1.4	-1.3	-1.2	-0.8	-0.4	0.1	[illegible]	0.4	0.8	1.2	1.5	1.9	2.0	2.2
May 1/84	LOCATION	2	1.5	-0.2	-0.4	-0.4	-0.3	-0.1	-0.1	0.2	0.1	0.5	0.1	1.3	1.4	1.6	1.9	1.9
June 9/84	LOCATION	2	8.4	5.6	3.0	1.0	0.0	-0.1	0.4	-0.1	0.4	0.1	0.6	0.8	1.0	1.4	1.5	1.5
Aug.24/84	LOCATION	2	15.2	13.6	13.3	12.9	11.1	11.0	9.5	8.9	9.5	8.1	7.5	7.0	5.8	5.1	5.3	4.9
	LOCATION																	

APPENDIX C

Leduc Results

FOOTING ELEVATION

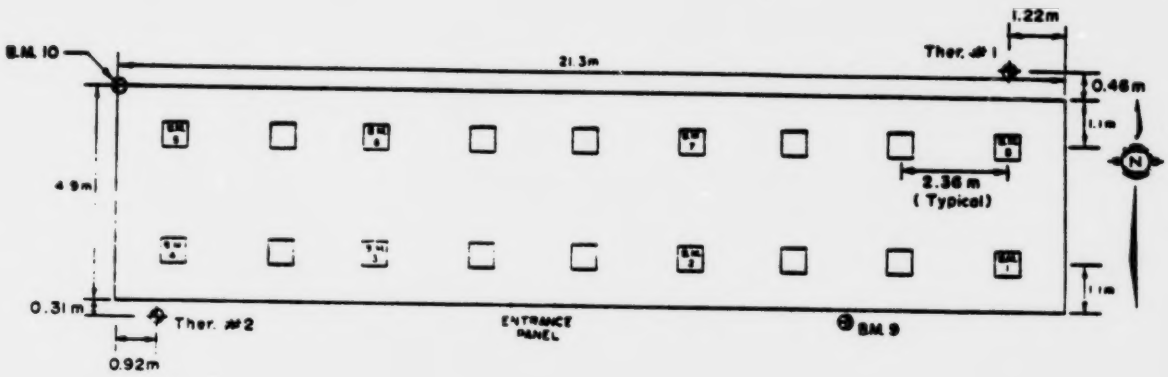
CLIENT: J.M. Mulligan & Associates Ltd.

PROJECT: Assessment of Manufactured Housing Foundation Systems

LOCATION: Willow Park Estates, Leduc, Alberta (Lot 155)

BENCHMARK: Top of Fire Hydrant, (in front of #87). Elevation= 100.000m

PROJECT No.: EGO 5830.2



B. M.	DATE / READINGS							
	12/13/83	12/29/83	1/30/84	2/28/84	3/27/84	15/6/84		
1	99.105	99.104	99.112	99.102	99.106	99.107		
2	99.144	99.142	99.148	99.137	99.142	99.138		
3	99.134	99.131	99.138	99.129	99.133	99.131		
4	99.097	99.093	99.100	99.091	99.097	99.097		
5	99.132	99.127	99.132	99.121	99.130	99.123		
6	99.123	99.119	99.125	99.115	99.122	99.113		
7	99.098	99.097	99.103	99.094	99.098	99.095		
8	98.976	98.974	98.982	98.971	99.974	99.973		
9	99.811	99.805	99.800	99.810	99.814	99.803		
10	99.725	99.721	99.722	99.719	99.723	99.712		

NOTE: BM. 9 – Gas Intake Line
BM.10 – Exterior Shirt

Ground elev. at Thermistor 1= 98.850 m
Ground elev. at Thermistor 2= 98.937 m

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT Assessment of Manufactured Housing Foundation Systems
Willow Park Estates, Lot 155, Leduc, Alberta

LOGGED/DWN. CA/RH | CKD. RH | DATE OF INVEST. Dec.9/83 | JOB NO. EG05830 | HOLE NO 1

DRILL TYPE: hand auger

WATER CONTENT — W_P - □ W - ○ W_L - △ PERCENT % (10 20 30 40 50 60)

DEPTH m ft | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE | OTHER TESTS

DATUM Top of Hydrant=100.000m

SURFACE ELEVATION 98.850 m

CLAY FILL, silty, sandy, stiff, low plastic, brown, organic incl., pebbles

CLAY TILL, silty, sandy, stiff to very stiff, medium plastic, brown, moist, coal chips, silt pockets, pebbles, sandstone and shale nodules

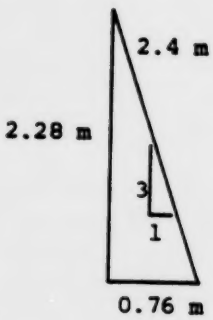
U1

U2

frozen

pp=320Kpa
γ= 2084.9Kg/m
γ_d= 1772.8 Kg/m

End of hole at 2.4m
Hole dry on completion
Thermistor string installed
Thermistor length= 2.4m
Hole backfilled with zonolite



Thermistor Inclination

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT: Assessment of Manufactured Housing Foundation Systems
Willow Park Estates, Lot 155, Leduc, Alberta

LOGGED/DWN.	CKD.	DATE OF INVEST.	JOB NO.	HOLE NO.
CA/RH	RH	Dec.9/83	EG05830	2

WATER CONTENT: W_P - □ W - ○ W_L - △ PERCENT % (10 20 30 40 50 60)

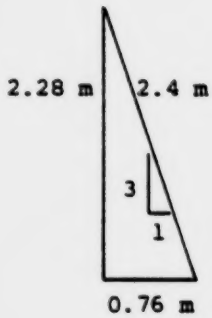
DEPTH m ft | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE | DRILL TYPE | OTHER TESTS

DATUM: Top of Hydrant=100.000m
SURFACE ELEVATION: 98.937 m

DRILL TYPE: hand auger

OTHER TESTS: frozen

m	ft	SOIL SYMBOL	SOIL DESCRIPTION
	1		TOPSOIL, silty, loose to compact, low plastic, black, organic incl., some sand
	2		
1	3		CLAY TILL, silty, sandy, low to medium plastic, stiff, brown, silt pockets, coal chips, pebbles to 25 mm ø, sandstone and shale nodules
	4		
	5		
	6		
2	7		
	8		
	9		End of hole at 2.4m Hole dry on completion Thermistor string installed Thermistor length = 2.4m Hole backfilled with zonolite
3	10		



Thermistor Inclination

MOBILE HOME FOUNDATION

SURVEY
FOR
PROVINCIAL GOVERNMENT OF ALBERTA
DEPARTMENT OF HOUSING
POLICY AND PLANNING DIVISION

CONSULTANT: J.M. MULLIGAN & ASSOCIATES LTD.
CONSULTING ENGINEERS

GEOTECHNICAL OFFICE: Edmonton

SURVEY DATA

MOBILE PARK: Willow Park Estates, Leduc
ADDRESS:
UNIT NO: Lot 155
OWNER: Dale Fort

PARK OWNER: Willow Park Estates, Ltd.
MANAGER:

DATUM: Assumed 100.000 m
LOCATION: Fire Hydrant at lot 87

DATE PROBE INSERTED December 9/83
NUMBER OF THERMISTORS: 2 Strings, 8 Thermistors per String DATE PROBE REMOVED:

TEMPERATURE READINGS

DATE	Depth (m)		0.28	0.57	0.85	1.14	1.42	1.72	1.99	2.28					Snow (mm)							
Dec. 13/83	LOCATION	1	-4.6	-0.8	1.8	3.0	4.0	4.9	5.8	5.8					50							
		2	-3.9	0	2.0	3.5	4.5	5.4	5.9	6.1					50							
Dec. 29/83	LOCATION	1	-9.5	-4.0	-1.0	1.5	3.0	4.0	4.5	5.0					100							
		2	-6.5	-2.5	-0.5	1.0	2.5	4.0	4.5	5.0					100							

DATE:	DEPTH (m)		0.38	.57	0.85	1.14	1.42	1.72	1.99	2.88					snow (mm)
Jan. 30/84	LOCATION	1	-0.5	0	0.5	1.5	2.0	3.0	3.5	4.0					25
		2	-1.0	-1.0	0	1.0	1.5	2.0	3.0	3.0					50
Feb. 28/84	LOCATION	1	-5.0	-2.5	-1.0	0	1.0	1.5	2.0	2.0					12 mm ice
		2	-2.0	-.5	0	.5	1.0	-	2.0	2.5					0
Apl. 27/84	LOCATION	1	3.5	3.0	3.0	3.0	3.5	3.5	3.5	3.5					0
		2	7.0	6.0	5.0	5.0	4.0	-	3.5	3.5					0
June 15/84	LOCATION	1	20.0	19.0	15.0	13.0	11.0	9.5	8.5	8.0					0
		2	14.0	13.0	11.0	10.0	8.5	-	7.0	6.5					0
	LOCATION														
	LOCATION														
	LOCATION														
	LOCATION														
	LOCATION														

APPENDIX D

Red Deer Results

FOOTING ELEVATION

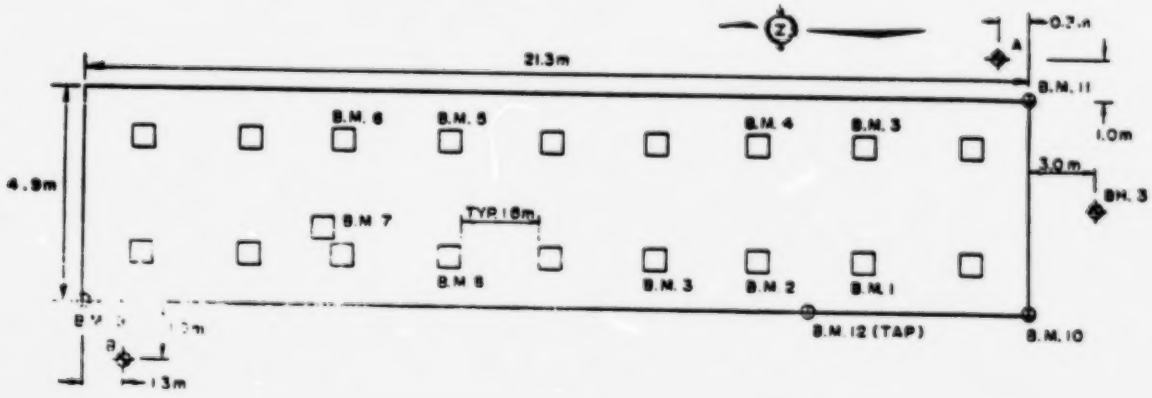
CLIENT: J.M. Mulligan & Associates Ltd.

PROJECT: Assessment of Manufactured Housing Foundation System

LOCATION: Parkside Mobile Estate, Red Deer (47 Parkside Drive, Unit #67)

BENCHMARK: Geodetic Benchmark = 881 - 200 m

PROJECT No.: EG-05830.3



B. M.	DATE/READINGS							
	Dec.21/83	Jan.6/84	Jan.16/84	Feb.2/84	Mar.8/84	Jun 25/84		
1	99.961	99.962	99.962	99.962	99.962	99.963		
2	99.985	99.989	99.989	99.989	99.989	99.989		
3	99.995	99.995	99.995	99.995	99.994	99.993		
4	99.987	99.987	99.987	99.987	99.984	99.986		
5	99.914	99.913	99.913	99.913	99.914	99.915		
6	99.995	99.995	99.995	99.995	99.996	99.996		
7	99.945	99.944	99.945	99.945	99.945	99.947		
8	99.944	99.943	99.944	99.944	99.945	99.945		
9	100.815	100.814	100.818	100.818	100.817	na		
10	100.800	100.798	100.800	100.802	100.801	100.801		
11	100.801	100.803	100.804	100.804	100.807	100.810		
12	101.053	101.052	101.053	101.053	101.055	101.052		

FOOTING ELEVATION

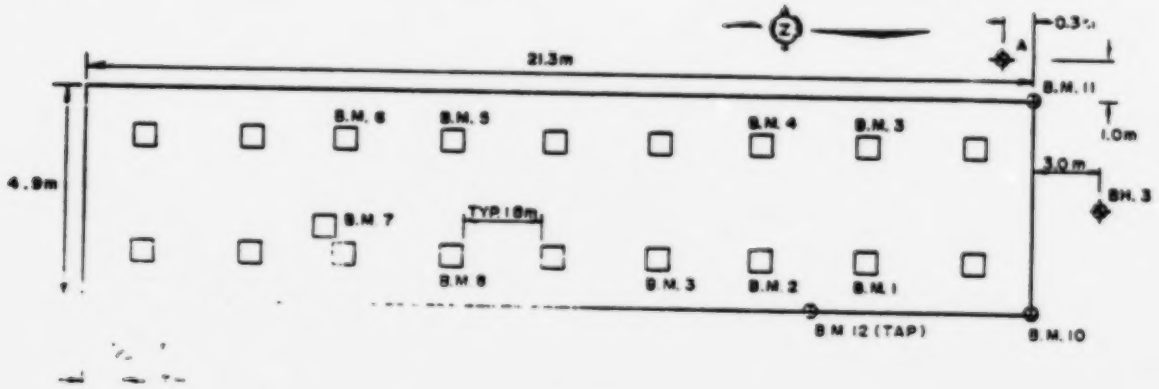
CLIENT: J.M. Mulligan & Associates Ltd.

PROJECT: Assessment of Manufactured Housing Foundation System

LOCATION: Parkside Mobile Estate, Red Deer (47 Parkside Drive, Unit #67)

BENCHMARK: Geodetic Benchmark = 881 - 200 m

PROJECT No.: EG-05830.3



B. M.	DATE/READINGS							
	Dec.21/83	Jan.6/84	Jan.16/84	Feb.2/84	Mar.8/84	Jun 25/84		
1	99.961	99.962	99.962	99.962	99.962	99.963		
2	99.085	99.989	99.989	99.989	99.989	99.989		
3	99.995	99.995	99.995	99.995	99.994	99.993		
4	99.987	99.987	99.987	99.987	99.984	99.986		
5	99.914	99.913	99.913	99.913	99.914	99.915		
6	99.995	99.995	99.995	99.995	99.996	99.996		
7	99.945	99.944	99.945	99.945	99.945	99.947		
8	99.944	99.943	99.944	99.944	99.945	99.945		
9	100.815	100.814	100.818	100.818	100.817	na		
10	100.800	100.798	100.800	100.802	100.801	100.801		
11	100.801	100.803	100.804	100.804	100.807	100.810		
12	101.053	101.052	101.053	101.053	101.055	101.052		

FOOTING ELEVATION

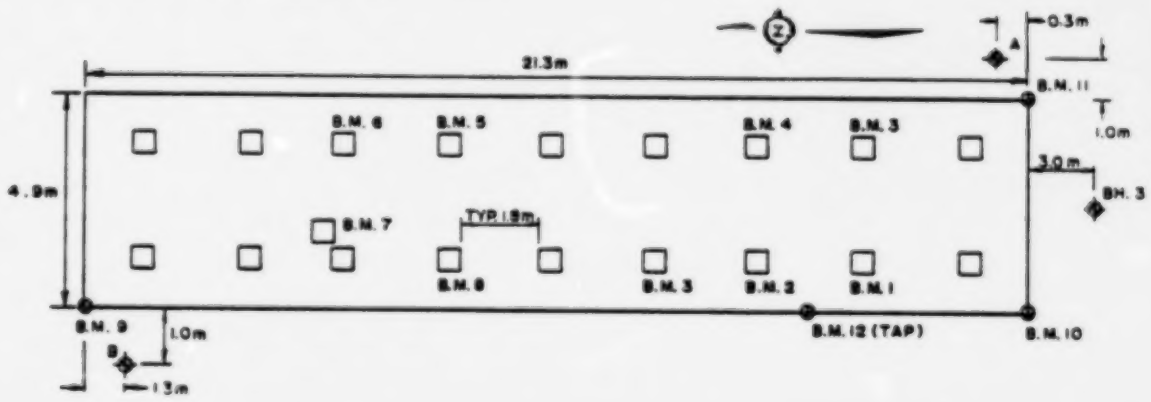
CLIENT: J.M. Mulligan & Associates Ltd.

PROJECT: Assessment of Manufactured Housing Foundation System

LOCATION: Parkside Mobile Estate, Red Deer (47 Parkside Drive, Unit #67)

BENCHMARK: Geodetic Benchmark = 881 - 200 m

PROJECT No.: EG-05830.3



B. M.	DATE/READINGS							
	Dec. 21/83	Jan. 6/84	Jan. 16/84	Feb. 2/84	Mar. 8/84			
1	99.961	99.962	99.962	99.962	99.962			
2	99.085	99.989	99.989	99.989	99.989			
3	99.995	99.995	99.995	99.995	99.994			
4	99.987	99.987	99.987	99.987	99.984			
5	99.914	99.913	99.913	99.913	99.914			
6	99.995	99.995	99.995	99.995	99.996			
7	99.945	99.944	99.945	99.945	99.945			
8	99.944	99.943	99.944	99.944	99.945			
9	100.815	100.814	100.818	100.818	100.817			
10	100.800	100.798	100.800	100.802	100.801			
11	100.801	100.803	100.804	100.804	100.807			
12	101.053	101.052	101.053	101.053	101.055			

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS
PARKSIDE MOBILE ESTATES, RED DEER

LOGGED/DWN. TGH | CKD. RST | DATE OF INVEST. Dec.20/83 | JOB NO. RX-02590 | HOLE NO A

DRILL TYPE: Solid Auger

WATER CONTENT: Wp - □ W - ○ W_L - △ PERCENT % (10 20 30 40 50 60)

DATUM Benchmark - Ground Rod

SURFACE ELEVATION 100.000 m

DEPTH m	DEPTH ft.	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE: CONDITION	SOIL SAMPLE: TYPE	SOIL SAMPLE: PENETRATION RESISTANCE	OTHER TESTS
	1		TOPSOIL,silty				
	2		SAND,little silt,compact,uniform, fine grained,brown				
1	3						
	4						
	5						
	6						
2	7		low plastic,silty,clay				
	8						
	9						
3	10		End of hole at 3.0 m Thermistors installed to 2.45 at 0.3 m intervals Hole backfilled with dry medium grained sand				

HT08 · 79/05

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT: ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS
PARKSIDE MOBILE ESTATES, RED DEER

LOGGED/DWN.	CKD.	DATE OF INVEST.	JOB NO.	HOLE NO
TGH	RST	Dec.20/83	RX-02590	B

DRILL TYPE: Solid Auger

DATUM: Benchmark - Ground Rod

SURFACE ELEVATION: 100.000 m

WATER CONTENT: W_P - □ W - ○ W_L - △ PERCENT % (10 20 30 40 50 60)

DEPTH	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE: CONDITION	SOIL SAMPLE: TYPE	SOIL SAMPLE: PENETRATION RESISTANCE	OTHER TESTS
0		TOPSOIL, organic silt and sand				
1		SAND, little silt, compact, uniform, layered, fine grained, brown, damp				
2						
3						
4						
5						
6		uniform, medium grained layer				
7						
8		low plastic, silty clay, layered, moist				
9						
10		End of hole at 3.0 m Thermistors installed to 2.45 m at 0.3 m intervals. Hole backfilled with dry medium grained sand				

HT08 · 79/05

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS
PARKSIDE MOBILE ESTATES, RED DEER

LOGGED/DWN. TGH/IS | CKD. RST | DATE OF INVEST. Dec.20/83 | JOB NO. RX-02590 | HOLE NO 3

DRILL TYPE: Solid Auger

WATER CONTENT
W_P - □ W - ○ W_L - △
PERCENT %
10 20 30 40 50 60

DEPTH | SOIL SYMBOL | SOIL DESCRIPTION

DATUM Benchmark - Ground Rod

SURFACE ELEVATION 100.000 m

SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE

OTHER TESTS

DEPTH		SOIL DESCRIPTION	CONDITION	TYPE
	1	SAND, trace to little silt, fine grained, uniform, light brown, occasional silt pockets		
	2			
1	3	trace of clay, white carbonate	X	A
	4	grey-brown, mottled		
	5	occasional grey silt layers		
2	6		X	A
	7	End of hole at 2.1 m Standpipe installed Dry to completion and after 11 days		
	8			
	9	Second PVC standpipe installed and survey benchmark rod driven 1 m below bottom of hole. Surface 100 mm above ground level		
3	10			

HTOB - 79/05

MOBILE HOME FOUNDATION

SURVEY
FOR
PROVINCIAL GOVERNMENT - ALBERTA
DEPARTMENT OF [illegible],
POLICY AND PLANNING SECTION

CONSULTANT: J.N. MUIR & ASSOCIATES LTD.
CONSULTING ENGINEERS

GEOTECHNICAL OFFICE :

SURVEY DATA

MOBILE PARK: Parkside Mobile Estates — NO: 67

ADDRESS: 47 Parkside Drive, Red Deer — R: Cindy Hoppis, Ray Roback

PARK OWNER: John Ratzke — GER: Casey Vanderleek

DATUM: GEODESIC ELEVATION — ATION:

DATE PROBE INSERTED: December 9, 1983
NUMBER OF THERMISTORS: 18
DATE PROBE REMOVED:

TEMPERATURE READINGS

DATE		DEPTH (m)	0.28	0.57	0.85	1.14	1.42	1.72	1.99	2.28	2.57					snow (mm)						
December 16, 1983	LOCATION	A	-12.3	-3.5	0	0.7	2.5	4.3	5.0	6.1	7.0					75						
		B	-10.8	-5.2	-2.6	0.2	2.8	4.0	4.9	5.6	6.7					75						
December 22, 1983	LOCATION	A	-14.5	-5.5	-1.7	1.2	2.0	3.9	4.6	5.5	6.7					130						
		B	-15.0	-9.0	-4.5	-1.0	1.5	3.5	4.4	5.3	6.3					130						

DATE:		DEPTH (m)	0.28	0.57	0.85	1.14	1.42	1.72	1.99	2.28	2.57	snow (mm)
Jan. 6/84	LOCATION	A	-0.8	-1.4	-1.0	0.2	0.8	2.5	3.3	4.3	5.5	300
		B	-0.9	-2.7	-2.8	-1.8	-0.2	1.5	2.5	3.7	5.0	0
Jan. 16/84	LOCATION	A	-3.1	-1.8	-0.8	0.5	0.7	2.5	2.6	4.0	4.0	400
		B	-5.0	-3.1	-2.2	-0.9	0.5	1.3	2.3	3.5	4.2	100
Fe. 2/84	LOCATION	A	-0.8	-0.7	0.5	0	0	0.6	2.5	3.5	4.5	40
		B	-0.8	-2.0	-1.8	-1.0	0	1.0	1.5	2.5	3.5	40
Mar. 8/84	LOCATION	A	-1.0	-0.4	0.3	0.5	0.5	1.8	2.0	2.8	3.5	-
		B	- .5	-0.4	0	0.5	1.0	1.5	2.0	2.5	3.5	-
June 25/84	LOCATION	A	28.0	15.5	14.0	12.5	10.5	9.0	8.5	8.0	7.0	-
		B	18.5	11.5	10.5	9.0	7.0	6.5	5.0	4.5	4.0	-
	LOCATION											
	LOCATION											
	LOCATION											
	LOCATION											

APPENDIX E

Calgary Results

FOOTING ELEVATION

CLIENT: J.M. MULLIGAN & ASSOCIATES LTD.

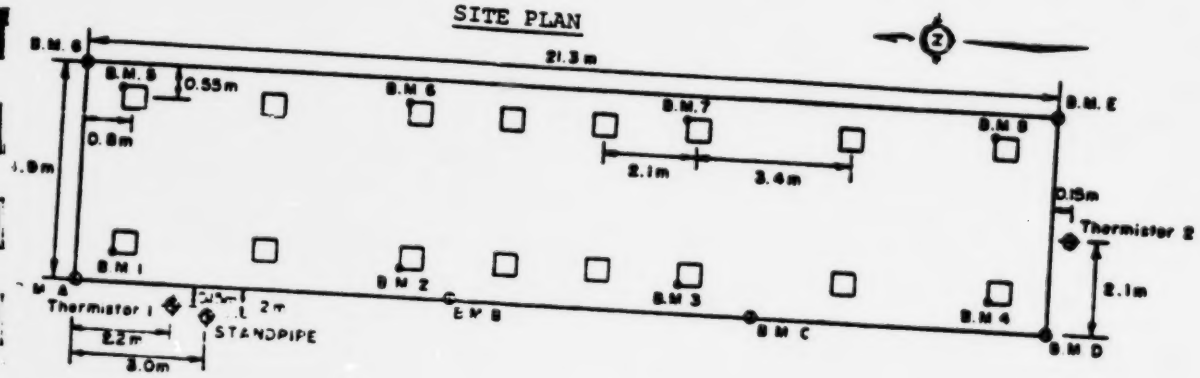
PROJECT: ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS

LOCATION: RED CARPET MOBILE HOME VILLAGE, CALGARY, ALBERTA (Unit #9)

BENCHMARK: GEODETIC 1056.876 m

PROJECT No.: EGO 5830.4

SITE PLAN



HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT ASSESSMENT OF MANUFACTURING HOUSING FOUNDATIONS SYSTEM
6220 - 17 AVENUE S.E., CALGARY

LOGGED/DWN.	CKD.	DATE OF INVEST.	JOB NO.	HOLE NO.
MM/CM	LM	Dec. 30/83	EG-05830.4	1

WATER CONTENT — Wp - □ W - ○ W_L - △ — PERCENT % — 10 20 30 40 50 60

DEPTH — m ft

SOIL SYMBOL

SOIL DESCRIPTION

DATUM Geodetic

SURFACE ELEVATION 1057.29 m

SOIL SAMPLE — CONDITION | TYPE | PENETRATION RESISTANCE

DRILL TYPE: Auger

OTHER TESTS

m	ft	SOIL DESCRIPTION	CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
	1	CLAY, silty, low to medium plastic, little sand and gravel, brown, frozen				
	2	unfrozen, till-text, moist, stiff				
1	3					
	4	coal inclusions		U1		pp = 192 kPa
	5					
	6					
2	7	occasional wet sand layers		U2		pp = 192 kPa
	8					
	9					
3	10					

Bottom of Hole at 3.3 m
Hole drilled at approximately 1 horizontal: 1 vertical slope
Standpipe Measurements: Standpipe installed to 3.0 m depth):
- Hole dry on completion, December 30, 1983
- G.W.L. at 2.4 m, measured on January 17, 1984
- G.W.L. at 2.6 m, measured on February 7, 1984
- G.W.L. at 1.77 m, measured on March 5, 1984
- G.W.L. at 1.75 m measured on April 13, 1984

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT ASSESSMENT OF MANUFACTURED HOUSING FOUNDATIONS SYSTEM
6220 - 17 AVENUE S.E., CALGARY

LOGGED/DWN.	CKD.	DATE OF INVEST.	JOB NO.	HOLE NO.
MM/CM	LM	Dec.30/83	EG-05830.4	2

DRILL TYPE: Auger

WATER CONTENT
W_P - □ W - ○ W_L - △
PERCENT %
10 20 30 40 50 60

DEPTH m ft

SOIL SYMBOL

SOIL DESCRIPTION
DATUM Geodetic
SURFACE ELEVATION 1057.47 m

SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE

OTHER TESTS

TOPSOIL,organic,silt,black

CLAY,silty,low plastic,little sand and gravel,occasional sand lenses,coal inclusions,brown frozen,till-text,moist,stiff

U1 — pp =288kPa; γ =23.6kN/m^3; γ_d =20.9kN/m^3

U2 — pp =240kPa; γ =22.3kN/m^3; γ_d =19.6kN/m^3

U3 — pp=240kPa; γ =21.9kN/m^3; γ_d=19.2kN/m^3

Bottom of Hole at 3.3 m
Hole drilled at approximately 1 horizontal: 1 vertical slope

MOBILE PARK: RED CARPET MOBILE HOME VILLAGE

UNIT NO: 9

100.00 m = 1056.876 m(Geodetic)

ELEVATION READINGS (m)

DATE \ STATION	1	2	3	4	5	6	7	8
Jan. 9/84	99.474	99.861	99.303	99.745	99.431	99.883	99.561	100.141
Jan. 20/84	99.478	99.865	99.305	99.746	99.430	99.885	99.561	100.143
Feb. 7/84	99.471	99.858	99.300	99.742	99.436	99.879	99.565	100.141
March 5/84	99.472	99.857	99.300	99.746	99.436	99.878	99.567	100.143
April 13/84	99.478	99.856	99.298	99.746	99.437	99.876	99.565	100.142
June 12/84	99.477	99.854	99.297	99.742	99.435	99.875	99.562	100.140

MOBILE PARK: RED CARPET MOBILE HOME VILLAGE

UNIT NO: 9

100.00 m = 1056.876^{m} (Geodetic)

ELEVATION READINGS(mIEXTERIOR READINGS)

STATION / DATE	A	B	C	D	E	F	G	
Jan. 20/84	101.120	101.131	100.863	101.207	100.620	100.579	100.550	
Feb. 7/84	101.120	101.127	100.862	101.204	100.619	100.576	100.548	
March 5/84	101.120	101.126	100.861	101.207	100.625	100.574	100.549	
April 13/84	101.123	101.125	100.866	100.209	100.625	100.564	100.550	
June 12/84	101.122	101.125	100.862	100.207	100.624	100.565	100.548	

MOBILE HOME FOUNDATION

SURVEY
FOR
PROVINCIAL GOVERNMENT OF ALBERTA
DEPARTMENT OF HOUSING
POLICY AND PLANNING DIVISION

CONSULTANT: J.M. MULLIGAN & ASSOCIATES LTD.
CONSULTING ENGINEERS

GEOTECHNICAL OFFICE :

SURVEY DATA

MOBILE PARK: Red Carpet Mobile Home Village
ADDRESS: 6220 - 17 Avenue S.E., Calgary
UNIT NO: 9
OWNER: Mr. E. Brigden

PARK OWNER:
MANAGER: Mr. J. S. Prettie

DATUM: GEODESIC ELEVATION
LOCATION:

DATE PROBE INSERTED: December 30, 1983
NUMBER OF THERMISTORS: 2 strings, 8 thermistors/string
DATE PROBE REMOVED:

TEMPERATURE READINGS (Celsius)

DATE	DEPTH (m)		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4					Snow (mm)							
Jan. 4/84	LOCATION	1	0.2	0.6	1.1	1.9	2.3	2.9	3.5	4.0					80							
		2	-0.2	-0.5	0.0	0.6	1.6	2.5	4.2	-					80							
Jan. 17/84	LOCATION	1	-2.5	-1.0	0.0	0.7	1.6	2.3	2.9	3.7					125							
		2	-0.7	0.3	1.1	1.7	2.3	2.8	3.2	3.6					125							

DATE: \ DEPTH (m)			0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4						snow (mm)
Feb. 7/84	LOCATION	1	-0.3	-0.2	0.0	0.6	1.3	2.0	2.6	3.2						40
		2	1.8	1.9	2.0	2.1	2.3	2.5	2.8	3.1						40
MARCH 5/84	LOCATION	1	-0.2	0.0	0.6	1.1	1.6	2.3	2.7	3.2						5
		2	2.0	2.0	2.1	2.4	2.4	2.7	2.9	3.1						-
April 13/84	LOCATION	1	5.4	4.4	3.7	3.5	3.4	3.4	3.7	3.9						-
		2	6.9	5.7	4.8	4.1	3.8	3.6	3.5	3.6						-
June 12/84	LOCATION	1	19.0	12.0	11.5	9.0	7.0	6.6	6.0	4.0						-
		2	21.0	13.6	12.5	9.5	8.2	7.0	6.0	4.0						-
	LOCATION															
	LOCATION															
	LOCATION															
	LOCATION															
	LOCATION															

APPENDIX F

Lethbridge Results

MOBILE HOME FOUNDATION

SURVEY
FOR
PROVINCIAL GOVERNMENT OF ALBERTA
DEPARTMENT OF HOUSING
POLICY AND PLANNING DIVISION

CONSULTANT: J.M. MULLIGAN & ASSOCIATES LTD.
CONSULTING ENGINEERS

GEOTECHNICAL OFFICE : Lethbridge

SURVEY DATA

MOBILE PARK:
UNIT NO: Lot 11
ADDRESS: 11410 - 43 Street South, Lethbridge T1K 3S5, Alta.
OWNER: J.F. Brown
PARK OWNER: Parkview Estates
MANAGER: Phil Demaere, 113 Parkview Estates
DATUM: GEODESIC ELEVATION
LOCATION:
DATE PROBE INSERTED January 3, 1984
NUMBER OF THERMISTORS: 2 strings, 8 thermistors per string
DATE PROBE REMOVED:

TEMPERATURE READINGS

DATE	Depth (m)		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4				Snow (mm)								
Jan.12/84	LOCATION	A	0.0	1.1	2.4	3.6	4.6	5.7	6.5	7.1				-								
		B	1.0	2.4	3.4	4.2	5.0	5.8	6.4	7.1				-								
Apr.25/84	LOCATION	A	5.0	5.0	4.8	4.2	4.7	5.7	6.8	7.1				-								
		B	6.5	6.4	5.4	4.8	5.0	5.8	--	7.1				-								

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT J.M. MULLIGAN & ASSOCIATES LTD.
ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS - LOT 11/11410 - 43 STREET, LETHBRIDGE

LOGGED/DWN.	CKD.	DATE OF INVEST.	JOB NO.	HOLE NO
JDF	RH	Jan. 3/84	EG-05830.5	2

WATER CONTENT — Wp - □ W - ○ W_L - △ — PERCENT % — 10 20 30 40 50 60

DEPTH m ft

SOIL SYMBOL

SOIL DESCRIPTION
DATUM
SURFACE ELEVATION

SOIL SAMPLE — CONDITION | TYPE | PENETRATION RESISTANCE

DRILL TYPE: Hand Auger

OTHER TESTS

CLAY, silty, fine to medium sand, grey, moist, occasional pebbles

C'

A1 (1 m)

A2 (2 m)

A3 (3 m)

A4 (3 m)

End of hole at 2.4 m
Thermistor string installed
Thermistor length = 2.4 m
Hole backfilled by zonoline

HT08 - 79

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

BOREHOLE LOG

PROJECT *J.M. MULLIGAN & ASSOCIATES LTD.*
ASSESSMENT OF MANUFACTURED HOUSING FOUNDATION SYSTEMS - LOT 11/11410 - 43 STREET, LETHBRIDGE

LOGGED/DWN.	CKD.	DATE OF INVEST.	JOB NO.	HOLE NO.
JDF	*RH*	*Jan. 3/84*	*EG-05830.5*	*1*

WATER CONTENT — W_P - □ W - ○ W_L - △ — PERCENT % — 10 20 30 40 50 60

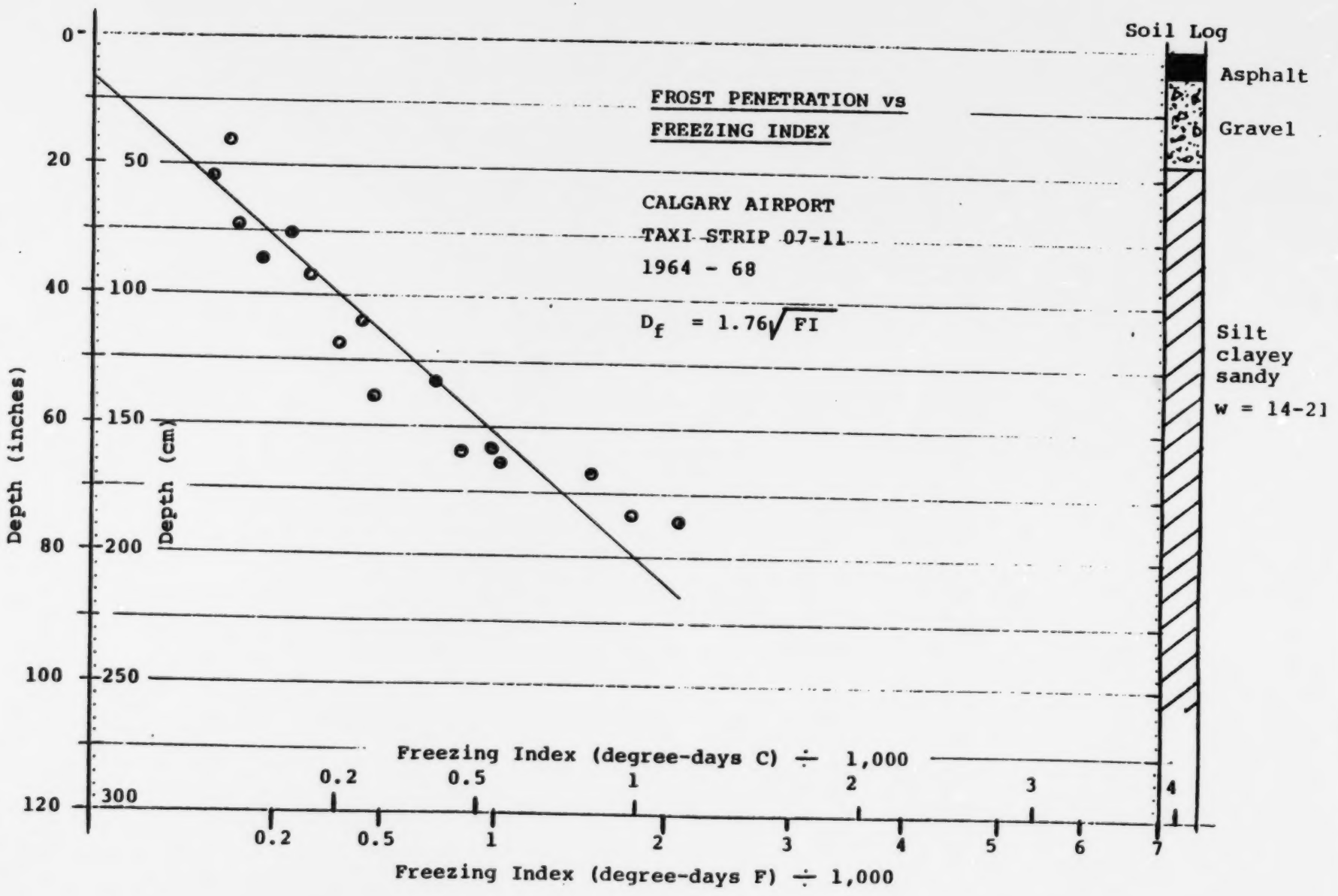
DRILL TYPE: *Hand Auger*

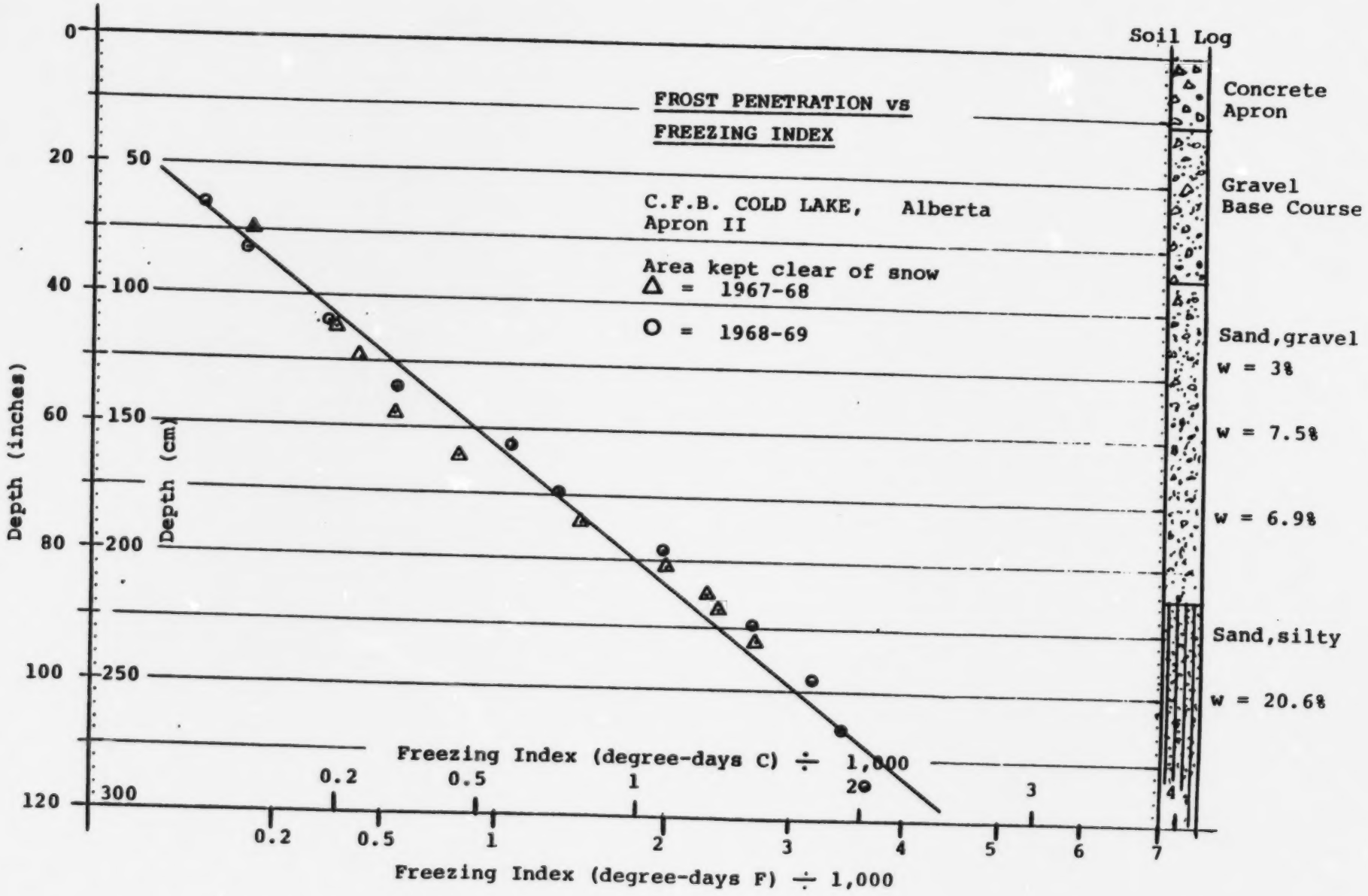
DEPTH m	DEPTH ft	SOIL SYMBOL	SOIL DESCRIPTION (DATUM / SURFACE ELEVATION)	SOIL SAMPLE: CONDITION	SOIL SAMPLE: TYPE	SOIL SAMPLE: PENETRATION RESISTANCE	OTHER TESTS
	1		*CLAY, silty, fine to medium sand, stiff, grey, moist, occasional pebbles*				
	2						
1	3						
	4						
	5						
	6						
2	7						
	8		*End of hole at 2.4 m*				
	9		*Thermistor string installed*				
	10		*Thermistor length = 2.4 m*				
3			*Hole backfilled with zonoline*				

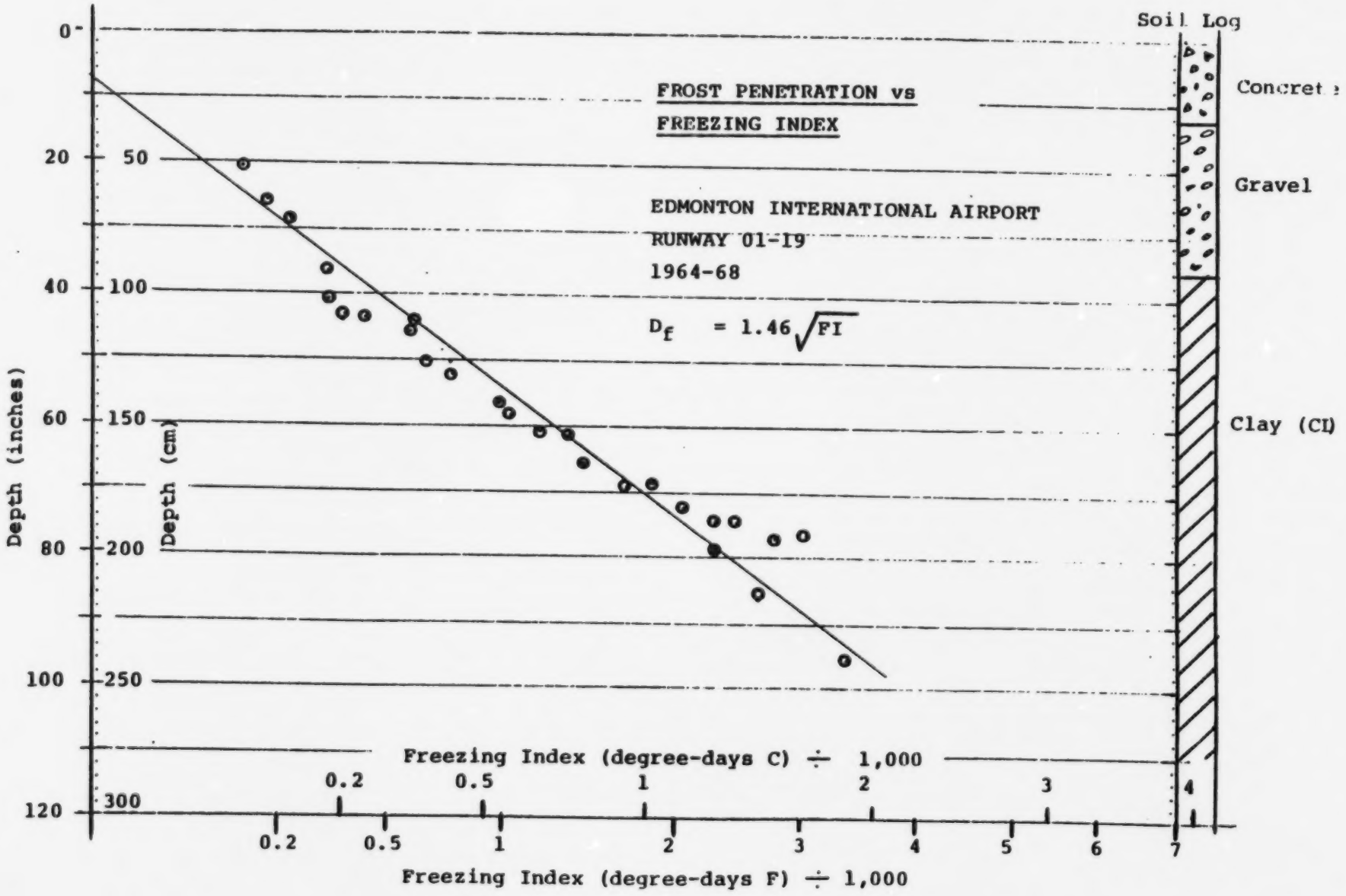
DATE:		DEPTH (m)	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4			snow (mm)
June 18/84	LOCATION	A	20.5	15.0	12.8	11.5	9.6	8.4	7.9	7.3			-
	LOCATION	B	20.8	15.0	13.2	11.6	9.9	9.0	8.3	7.4			-
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												
	LOCATION												

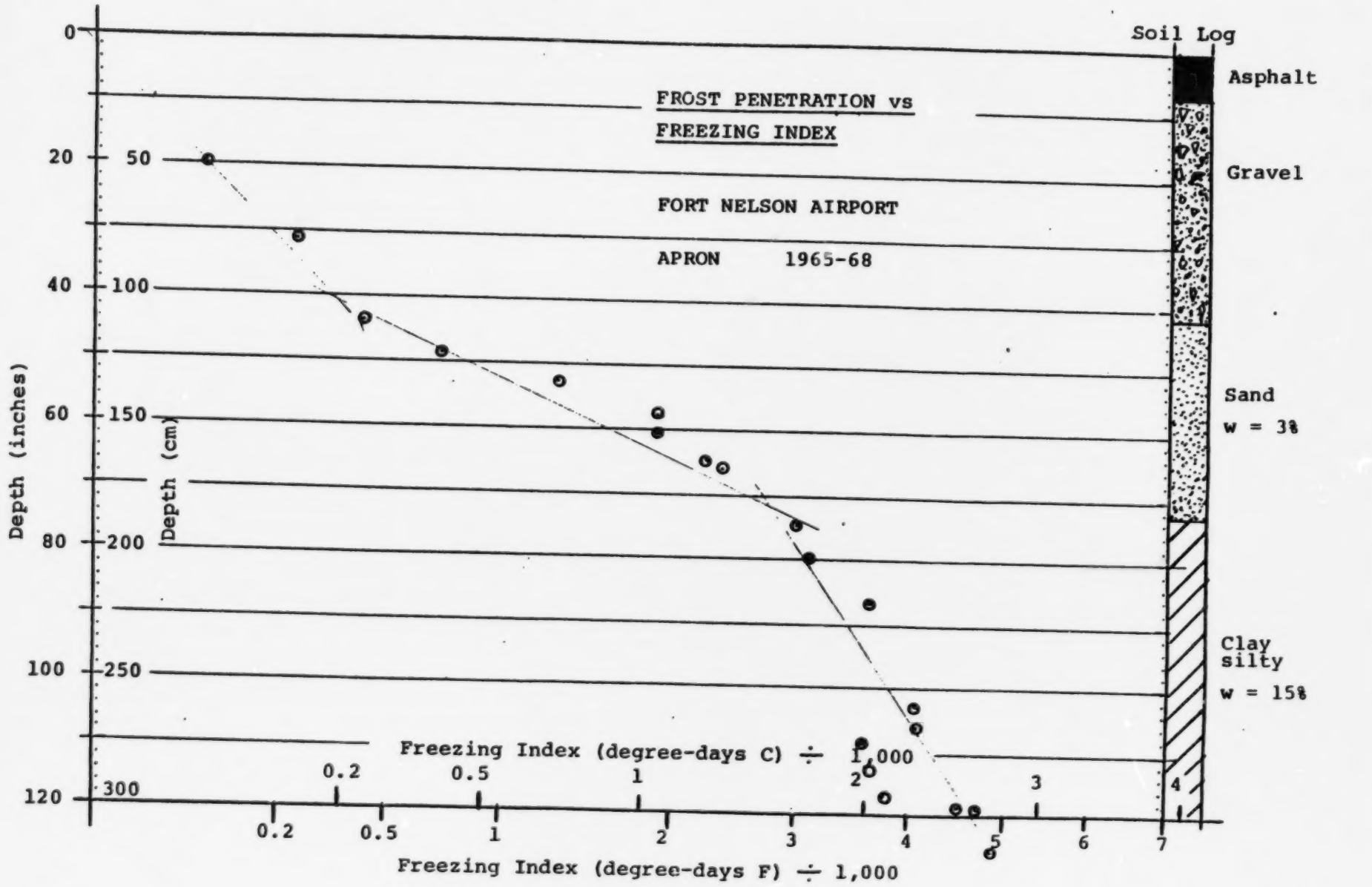
APPENDIX G

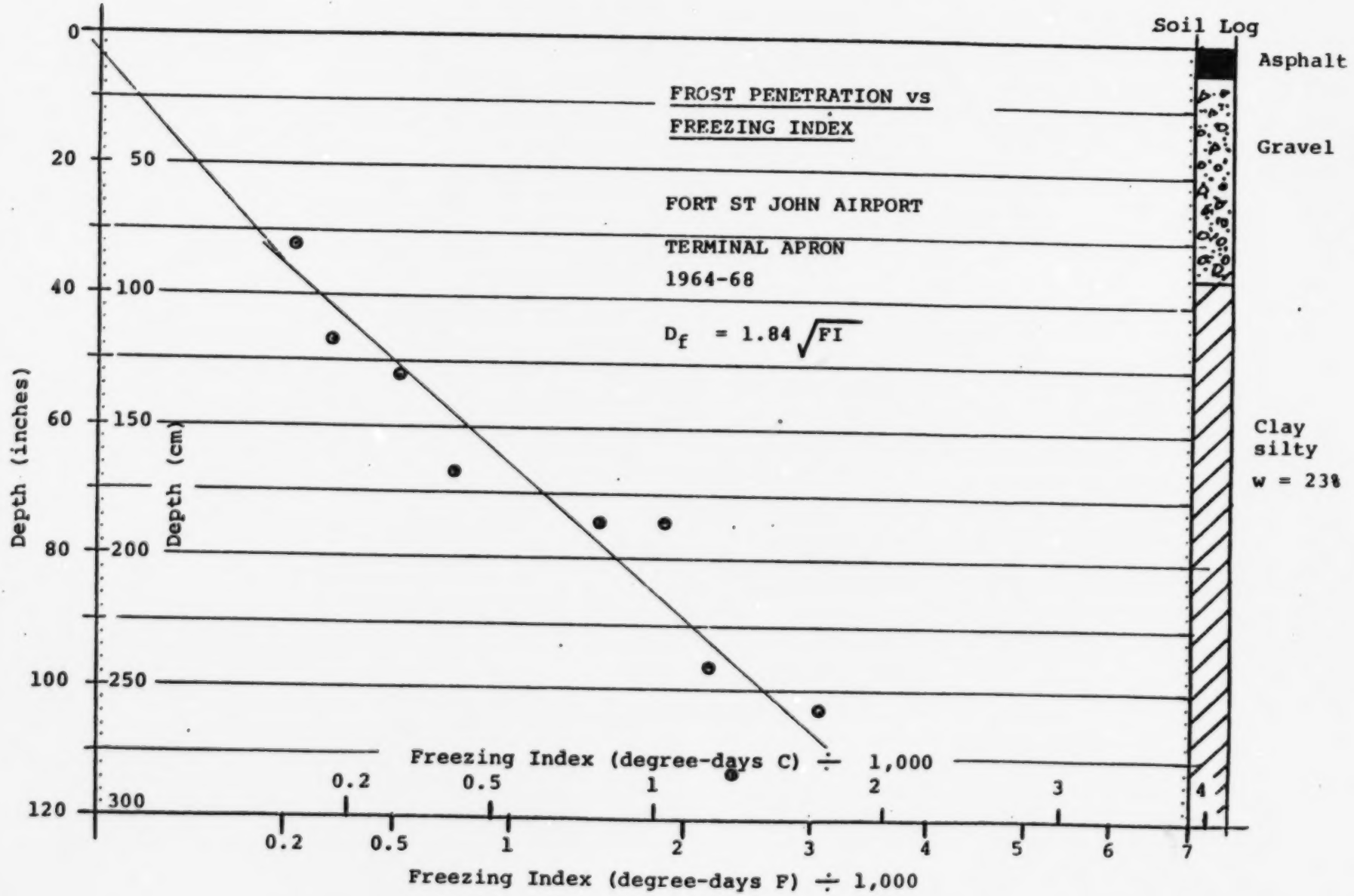
Frost Penetration at Canadian Airports

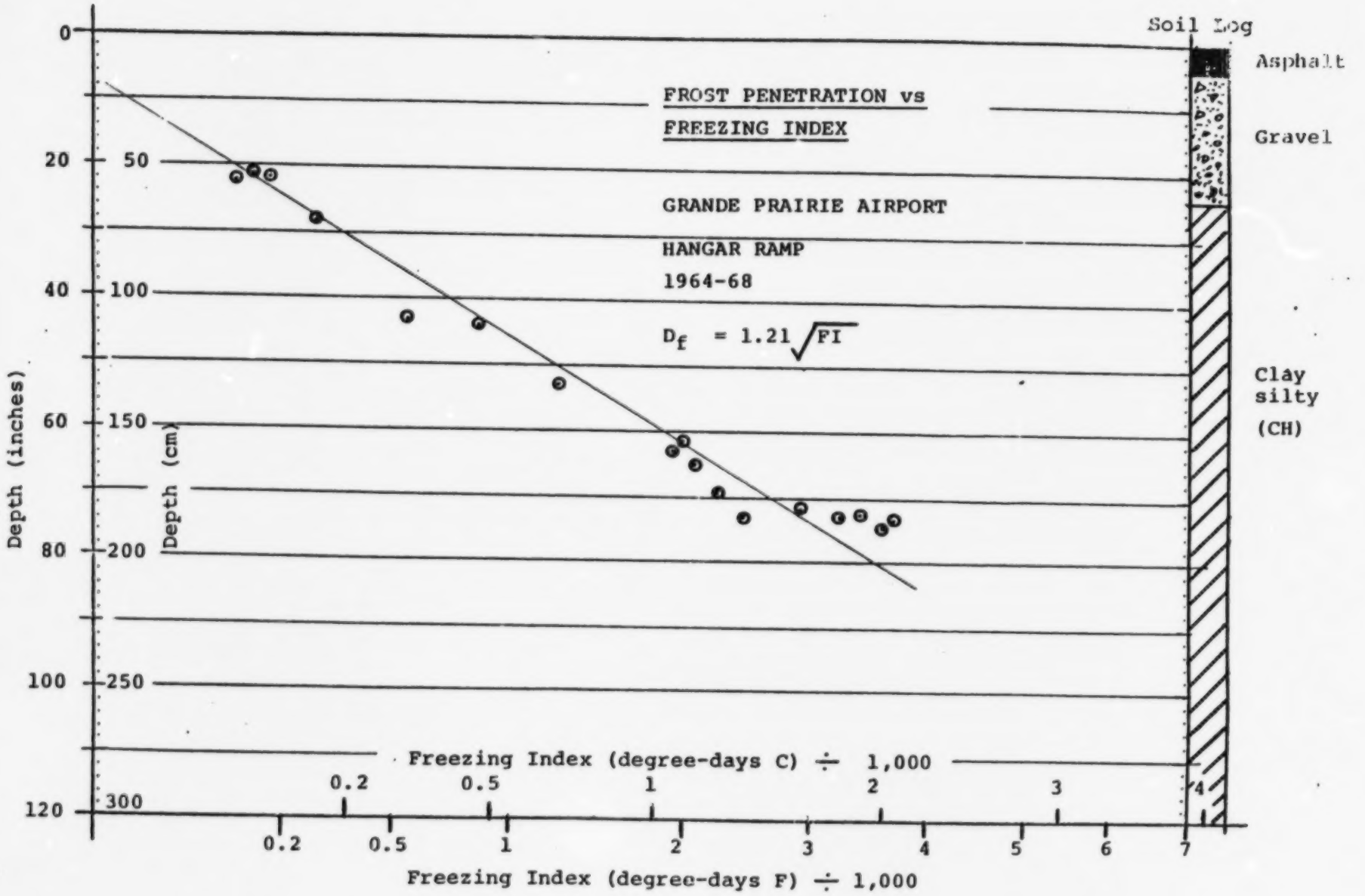

FROST PENETRATION vs
FREEZING INDEX
CALGARY AIRPORT
TAXI STRIP 07-11
1964 - 68
$D_f = 1.76\sqrt{FI}$
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7
Soil Log
Asphalt
Gravel
Silt
clayey
sandy
w = 14-21

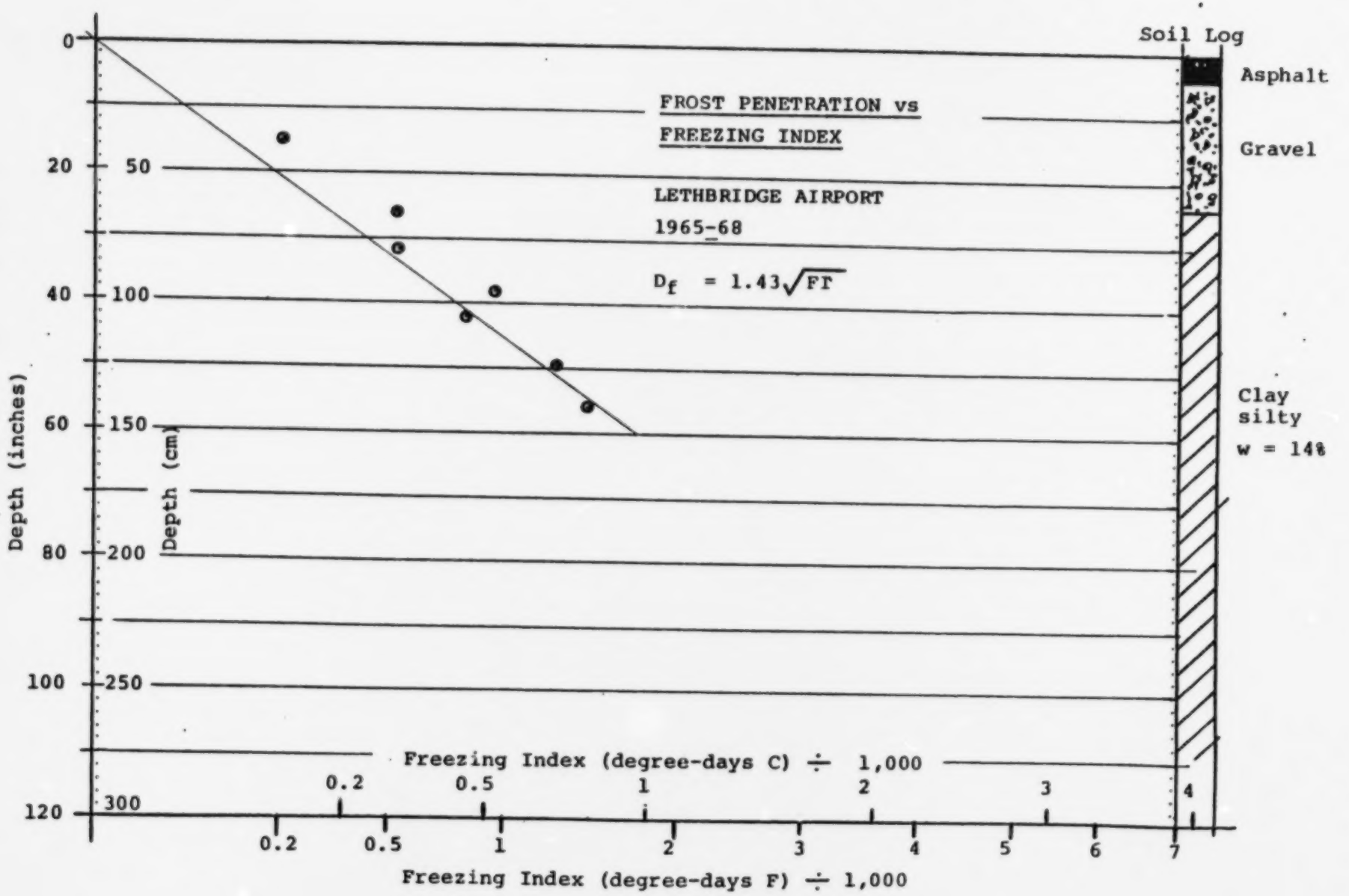

FROST PENETRATION vs
FREEZING INDEX
C.F.B. COLD LAKE, Alberta
Apron II
Area kept clear of snow
Δ = 1967-68
O = 1968-69
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7
Soil Log
Concrete Apron
Gravel Base Course
Sand,gravel
w = 3%
w = 7.5%
w = 6.9%
Sand,silty
w = 20.6%

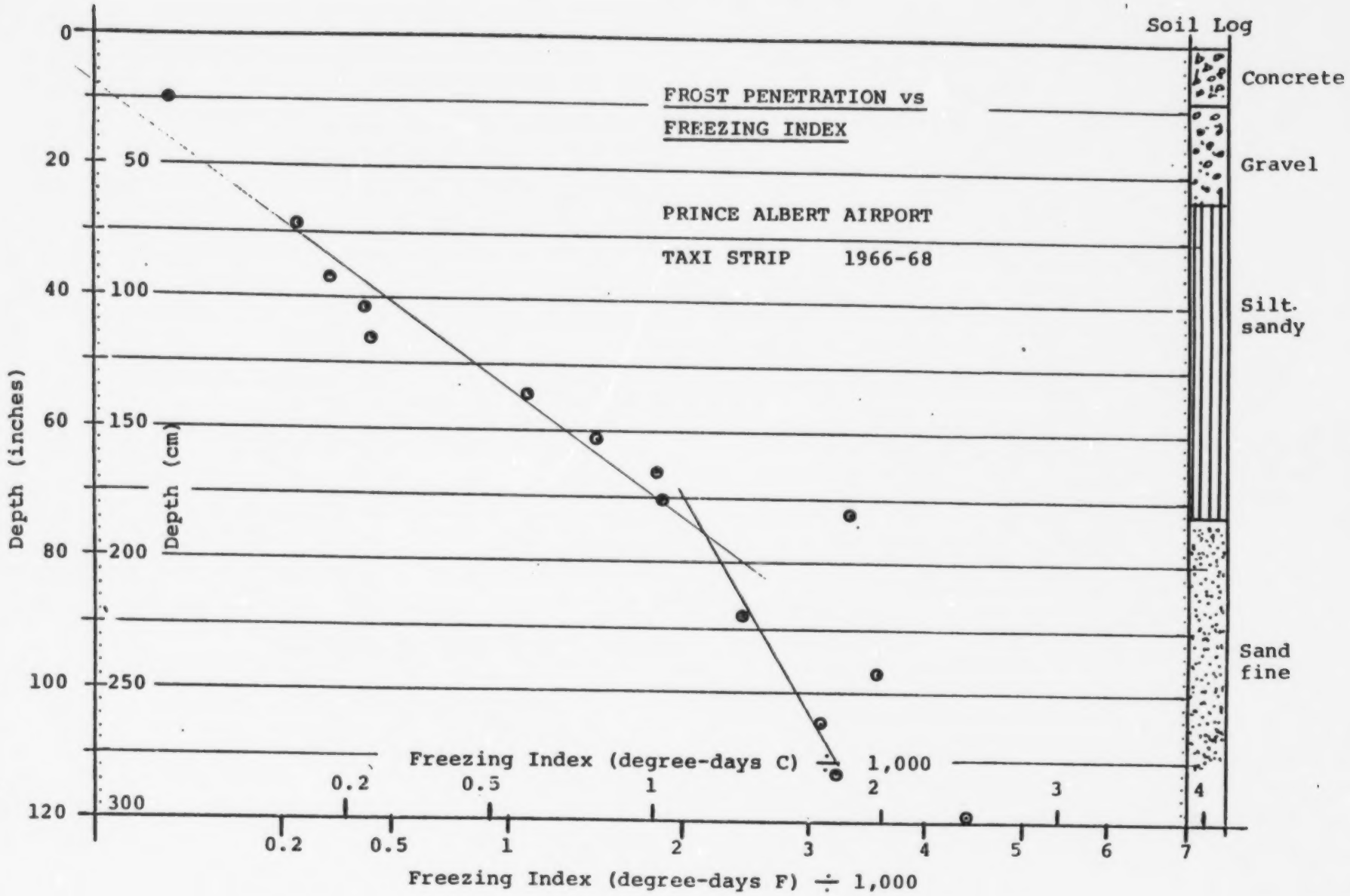

FROST PENETRATION vs
FREEZING INDEX
EDMONTON INTERNATIONAL AIRPORT
RUNWAY 01-19
1964-68
$D_f = 1.46\sqrt{FI}$
Soil Log
Concrete
Gravel
Clay (CL)
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7

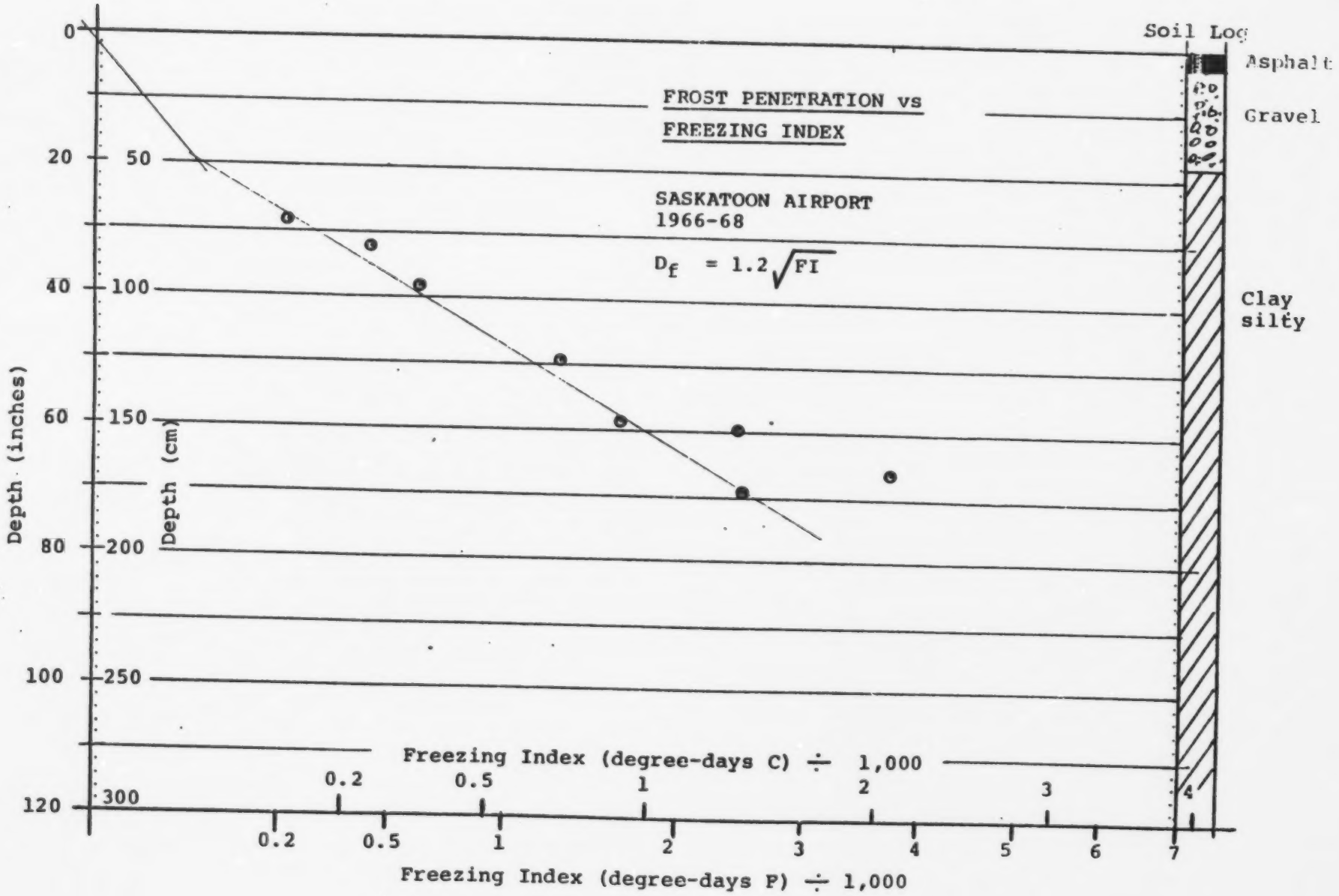

FROST PENETRATION vs
FREEZING INDEX
FORT NELSON AIRPORT
APRON 1965-68
Soil Log
Asphalt
Gravel
Sand
w = 3%
Clay
silty
w = 15%
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7

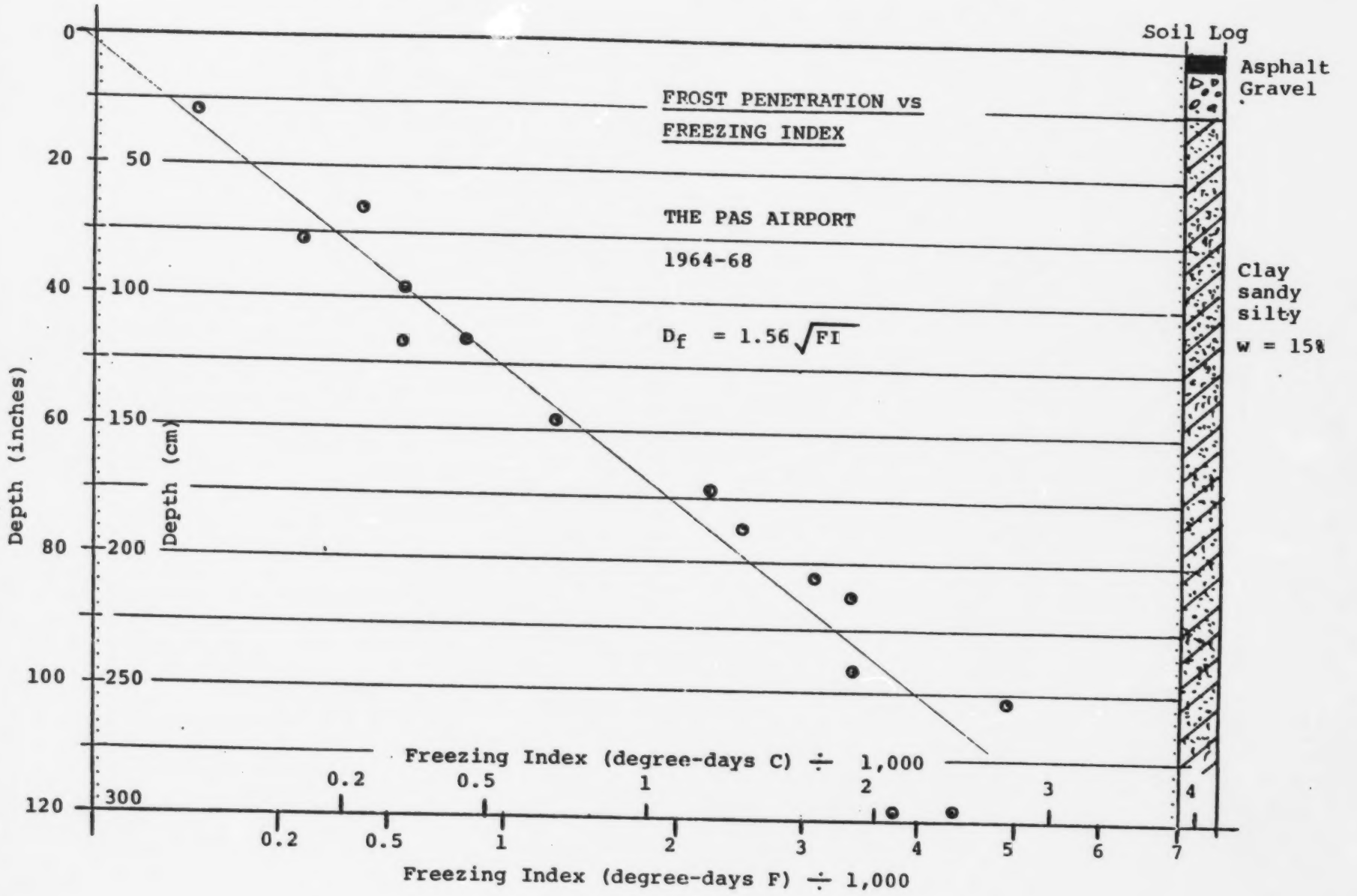

FROST PENETRATION vs
FREEZING INDEX
FORT ST JOHN AIRPORT
TERMINAL APRON
1964-68
$D_f = 1.84\sqrt{FI}$
Soil Log
Asphalt
Gravel
Clay
silty
w = 23%
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7

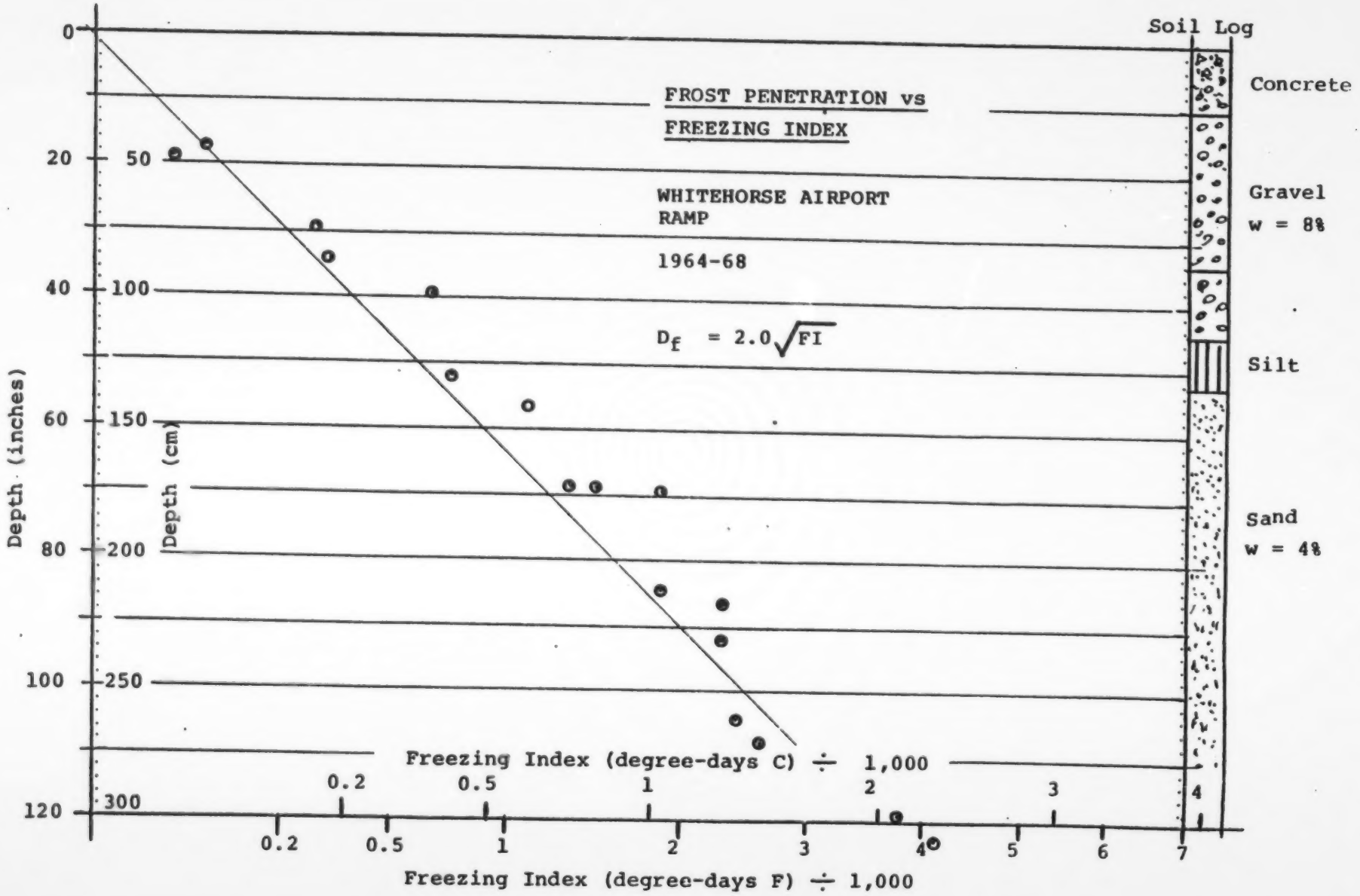

FROST PENETRATION vs
FREEZING INDEX
GRANDE PRAIRIE AIRPORT
HANGAR RAMP
1964-68
$D_f = 1.21\sqrt{FI}$
Soil Log
Asphalt
Gravel
Clay
silty
(CH)
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7

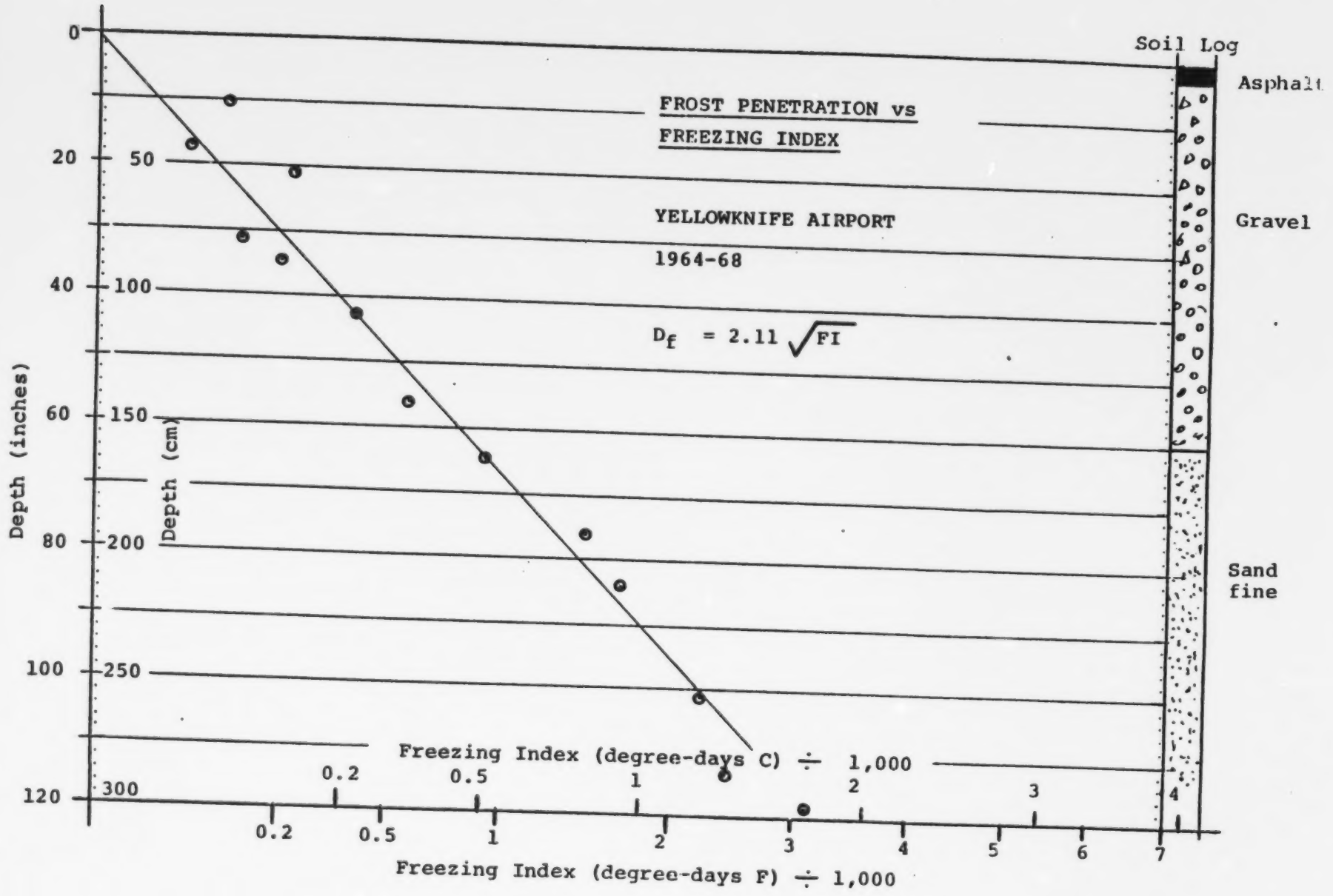

FROST PENETRATION vs
FREEZING INDEX
LETHBRIDGE AIRPORT
1965-68
$D_f = 1.43\sqrt{FI}$
Soil Log
Asphalt
Gravel
Clay
silty
w = 14%
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7


FROST PENETRATION vs
FREEZING INDEX
PRINCE ALBERT AIRPORT
TAXI STRIP 1966-68
Soil Log
Concrete
Gravel
Silt. sandy
Sand fine
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7


FROST PENETRATION vs
FREEZING INDEX
SASKATOON AIRPORT
1966-68
$D_f = 1.2\sqrt{FI}$
Soil Log
Asphalt
Gravel
Clay
silty
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days P) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7


FROST PENETRATION vs
FREEZING INDEX
THE PAS AIRPORT
1964-68
$D_f = 1.56\sqrt{FI}$
Soil Log
Asphalt
Gravel
Clay
sandy
silty
w = 15%
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7


FROST PENETRATION vs
FREEZING INDEX
WHITEHORSE AIRPORT
RAMP
1964-68
$D_f = 2.0\sqrt{FI}$
Soil Log
Concrete
Gravel
w = 8%
Silt
Sand
w = 4%
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7


FROST PENETRATION vs
FREEZING INDEX
YELLOWKNIFE AIRPORT
1964-68
$D_f = 2.11\sqrt{FI}$
Soil Log
Asphalt
Gravel
Sand
fine
Depth (inches)
Depth (cm)
0
20
40
60
80
100
120
50
100
150
200
250
300
Freezing Index (degree-days C) ÷ 1,000
0.2
0.5
1
2
3
4
Freezing Index (degree-days F) ÷ 1,000
0.2
0.5
1
2
3
4
5
6
7

APPENDIX H

DAILY TEMPERATURES

DAILY TEMPERATURES (C°)

October - 1983

Day	FORT MCMURRAY		LEDUC		CALGARY		RED DEER		LETHBRIDGE	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1	-2.5	17.7	-5.8	15.4	-5.8	15.5	-9.0	15.0	-8.0	16.1
2	0.7	9.4	-0.5	11.4	-1.2	10.7	-3.1	13.4	2.6	10.9
3	3.9	13.2	-0.5	16.9	-1.0	18.0	-4.5	16.0	-1.0	18.1
4	2.9	8.3	+2.0	11.2	1.8	13.8	0.2	13.2	4.4	15.3
5	-4.6	4.0	-2.0	12.5	-1.7	12.4	-1.5	13.4	-3.4	14.7
6	-9.0	9.7	-0.4	10.5	-5.6	13.1	-7.0	11.6	0.2	15.6
7	-3.8	10,4	-3.0	13.0	-2.3	11.2	-4.0	12.1	-0.7	14.4
8	-5.0	13.1	-7.2	15.4	-6.8	18.4	-8.8	14.2	-2.3	21.1
9	-0.6	11.4	-3.4	13.0	-2.1	14.9	-3.4	14.7	4.2	17.2
10	-7.4	0.2	-1.3	5.1	-4.2	8.0	-5.2	7.2	0.7	12.4
11	-8.9	7.0	-1.2	16.1	-5.5	14.8	0.2	14.8	-2.1	15.7
12	-3.4	14.4	-0.1	18.0	1.0	20.0	-4.4	19.3	1.9	21.2
13	-2.7	12.0	1.5	15.0	-0.9	13.9	0.7	15.8	0.9	17.0
14	2.8	5.8	1.8	9.4	3.2	9.0	2.7	9.4	4.7	15.2
15	-1.5	3.3	-4.0	2.9	0.0	3.4	-1.0	4.4	1.8	7.1
16	-7.0	-1.3	-5.4	3.4	-1.7	4.6	-3.1	3.7	-2.8	9.6
17	-8.7	4.3	-6.4	7.0	-4.2	3.8	-5.4	4.0	-7.3	14.0
18	-2.4	11.6	-7.0	11.4	-4.0	11.7	-8.9	11.0	0.7	12.4
19	-0.5	10.5	-2.2	14.3	-1.0	15.8	-4.4	13.6	-0.8	13.9
20	1.3	14.8	-3.1	15.3	3.0	14.5	-3.4	14.5	3.6	14.8
21	-1.0	14.8	-4.0	16.0	-1.5	15.7	-5.0	16.5	1.7	18.3
22	2.0	12.2	0.1	13.2	-0.6	16.5	1.8	15.2	6.0	20.1
23	0.8	8.4	-3.8	9.6	-3.9	11.3	-6.9	9.3	3.3	12.2
24	-1.9	8.5	-6.9	7.9	-8.1	9.8	-10.4	10.2	-4.3	12.4
25	-1.0	12.5	-1.6	15.2	2.1	17.1	-2.6	13.6	6.4	20.2
26	0.9	12.0	0.0	12.8	0.9	23.4	-1.8	15.3	8.7	24.5
27	-1.7	3.8	-3.3	5.5	-0.5	15.2	-5.5	5.8	-3.6	17.5
28	-5.2	9.2	-5.4	8.2	-3.8	11.8	-6.8	9,5	-7.6	17.7
29	-3.0	13.8	-6.2	14.6	-2.5	17.4	-8.0	16.6	2.6	20.0
30	0.0	10.7	-3.0	16.4	-1.3	18.9	-4.5	20.1	5.2	22.5
31	-0.2	4.4	1.3	10.5	5.5	17.9	-1.8	12.5	6.5	16.7

DAILY TEMPERATURES (C^{o})

November - 1983

Day	FORT MCMURRAY		LEDUC		CALGARY		RED DEER		LETHBRIDGE	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1	-6.7	3.3	5.1	2.1	-0.1	5.7	2.0	6.5	3.0	11.8
2	-2.6	3.2	7.4	1.0	0.5	14.3	-1.7	11.2	3.6	12.7
3	-2.2	6.8	11.6	-3.7	-1.8	18.2	-5.0	15.4	5.0	19.4
4	-3.0	3.6	12.5	-0.6	1.0	13.0	-3.5	14.4	3.8	14.4
5	-0.4	5.6	8.6	-4.0	-3.2	8.5	-8.6	8.9	-1.3	10.6
6	-4.2	1.3	8.5	-5.4	-4.1	12.9	-6.0	11.7	-1.4	14.9
7	-4.8	0.2	2.4	-6.3	-6.1	4.1	-5.9	3.4	-8.6	6.6
8	-6.9	-3.8	-0.8	-5.9	-10.1	6.5	-11.4	1.1	-9.8	7.8
9	-8.3	-4.8	-2.6	-4.8	-4.6	-2.6	-5.0	-2.9	-7.0	-1.4
10	-6.7	-3.8	-2.5	-6.4	-5.2	-3.4	-9.4	-2.8	-6.0	-2.3
11	-5.6	-0.9	1.2	-3.7	-4.3	8.0	-4.2	1.5	-3.4	10.7
12	-1.6	0.8	7.0	-7.8	-3.9	8.3	-6.8	8.0	1.1	9.7
13	-4.2	0.3	-1.1	-6.5	-2.5	9.3	-7.6	7.1	-2.0	10.0
14	-4.8	-2.4	4.0	-9.4	-6.2	8.9	-10.9	4.9	-0.6	9.9
15	-4.3	-0.6	2.2	-6.0	-1.5	10.4	-7.2	7.2	-1.3	13.1
16	-2.2	-0.9	-2.2	-7.8	-1.2	11.0	-1.5	8.1	2.5	11.2
17	-2.1	-1.0	0.1	-6.6	-0.3	8.5	-5.5	6.4	-1.9	8.5
18	-3.2	-1.4	0.0	-3.8	-5.3	7.9	-2.2	5.0	2.2	10.0
19	-3.6	-1.7	0.7	-3.8	-8.0	-1.6	-1.4	0.5	-8.2	2.2
20	-5.4	-2.5	-0.2	-3.2	-5.6	-1.4	-2.5	0.3	-3.9	-2.3
21	-7.2	-4.6	-1.4	-15.0	-14.8	-2.9	-13.5	-2.0	-4.7	-2.2
22	-7.8	-5.2	-5.7	-15.5	-14.2	-6.0	-13.4	-4.6	-12.7	-0.6
23	-9,3	-5.8	-5.9	-9.4	-19.8	-5.5	-9.9	-6.0	-15.2	-6.9
24	-16.8	-6.9	-7.6	-15.2	-13.6	-2.7	-15.3	-5.0	-15.7	-1.6
25	-20.3	-7.4	-9.0	-20.6	-11.2	-6.1	-10.9	-8.8	-12.2	-5.7
26	-12.3	-8.4	-5.4	-15.8	-14.8	-5.9	-13.7	-7.6	-18.8	0
27	-14.9	-6.8	0.2	-13.6	-9.0	1.7	-12.3	0.5	-1.1	3.4
28	-11.6	-8.4	-1.0	-13.2	-12.4	-2.1	-11.0	-1.3	-7.0	-0.9
29	-11.0	-9.2	-10.3	-19.2	-21.4	-7.6	-21.1	-9.6	-18.6	-7.0
30	-16.8	-8.4	-13.4	-23.3	-25.3	-11.4	-22.7	-13.3	-25.8	-14.7
31										

DAILY TEMPERATURES (C°)

December - 1983

Day	FORT MCMURRAY		LEDUC		CALGARY		RED DEER		LETHBRIDGE	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1	-21.1	-8.0	-21.2	-11.5	-18.2	-5.4	-22.0	-7.0	-23.4	-6.6
2	-19.6	-7.5	-20.2	-9.4	-17.0	1.3	-18.0	-8.1	-22.7	0.2
3	-19.0	-13.1	-13.8	-6.0	-15.5	-1.9	-14.7	-4.2	-16.9	-0.5
4	-24.4	-17.7	-14.7	-4.0	-16.5	-4.5	-15.5	-5.2	-15.3	-4.2
5	-20.8	-13.7	-11.9	-5.2	-14.8	-3.0	-14.6	-6.7	-13.6	-2.8
6	-20.8	-6.5	-11.4	-6.8	-19.7	-7.0	-14.9	-7.9	-18.8	-5.2
7	-28.9	-20.8	-31.5	-7.9	-20.1	-9.7	-25.4	-9.2	-19.3	-12.1
8	-31.3	-23.8	-36.4	-20.6	-24.2	-18.8	-28.0	-18.2	-21.4	-15.6
9	-25.7	-15.5	-21.2	-18.5	-22.5	-19.1	-21.1	-19.6	-21.0	-17.4
10	-28.8	-15.5	-24.8	-18.5	-20.0	-15.5	-24.8	-18.8	-21.6	-14.9
11	-19.8	-14.8	-23.6	-12.4	-20.5	0.6	-25.0	-9.3	-22.8	0.6
12	-20.2	-15.5	-24.5	-9.2	-13.2	0.7	-21.5	-6.6	-11.3	0.8
13	-27.8	-18.2	-18.7	-9.3	-16.2	0.6	-17.0	-10.8	-15.6	3.9
14	-35.5	-27.8	-29.9	-18.4	-19.7	-14.5	-20.7	-15.0	-17.1	-14.0
15	-33.0	-26.9	-25.1	-20.1	-21.5	-15.4	-22.6	-17.1	-24.9	-16.5
16	-33.9	-26.3	-29.5	-23.4	-30.0	-20.4	-31.0	-21.0	-31.6	-17.8
17	-30.6	-23.2	-31.3	-22.2	-31.5	-19.0	-32.1	-21.4	-32.8	-22.0
18	-35.0	-25.7	-34.3	-24.8	-31.6	-19.5	-31.5	-22.6	-33.2	-19.1
19	-32.2	-25.4	-35.5	-24.7	-31.4	-19.4	-34.0	-19.9	-33.8	-23.3
20	-31.8	-25.5	-32.4	-25.2	-31.5	-21.6	-31.6	-23.5	-31.6	-23.0
21	-31.8	-25.5	-29.5	-18.1	-30.5	-19.0	-29.1	-18.0	-31.4	-20.6
22	-33.6	-26.2	-26.9	-22.6	-27.6	-20.8	-26.2	-21.4	-31.6	-21.2
23	-39.3	-30.0	-37.3	-25.6	-36.5	-24.7	-37.0	-24.3	-38.7	-23.7
24	-30.8	-14.9	-36.9	-16.4	-36.1	-20.2	-38.9	-27.2	-39.2	-24.6
25	-17.6	-8.5	-16.6	-10.9	-26.8	-13.7	-30.0	-13.8	-28.2	-18.2
26	-13.3	-8.7	-16.8	-10.5	-22.4	-11.8	-16.5	-11.4	-19.8	-11.1
27	-18.4	-9.7	-21.3	-10.9	-25.0	-9.8	-27.0	-11.4	-26.4	-9.8
28	-22.8	-15.2	-22.1	-14.4	-27.3	-14.0	-29.1	-18.4	-27.4	-17.0
29	-21.0	-9.8	-26.6	-15.7	-27.4	1.6	-30.1	-20.4	-25.9	-0.6
30	-26.7	-15.2	-25.0	-7.2	-15.3	4.6	-23.6	-5.4	-1.0	4.4
31	-21.5	-8.7	-8.4	1.8	-13.9	4.9	-14.9	1.8	0.1	3.6

DAILY TEMPERATURES (C^{o})

January - 1984

Day	FORT MCMURRAY		LEDUC		CALGARY		RED DEER		LETHBRIDGE	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1	-18.0	-5.6	-8.7	-0.3	-2.3	8.0	-15.2	-2.0	-0.2	6.6
2	-12.6	7.2	-5.1	6.3	1.5	11.0	-5.5	8.0	2.7	8.0
3	-14.0	5.7	-6.1	1.6	-2.3	7.1	-8.0	2.4	3.9	9.4
4	-13.3	6.9	0.4	5.6	-1.0	12.2	-2.8	10.0	5.5	16.0
5	-8.2	-2.3	-3.2	4.5	-2.8	8.0	-4.8	4.4	6.5	12.1
6	-19.3	-0.4	-4.3	2.2	-1.6	6.5	-6.1	1.6	-1.0	11.1
7	-22.8	-16.2	-6.0	-1.1	-5.8	-0.7	-6.1	-3.2	-4.4	-0.3
8	-26.2	-19.2	-9.2	-4.4	-7.4	-4.0	-9.1	-5.1	-4.4	-2.3
9	-32.0	-23.2	-14.5	-8.4	-11.0	-4.9	-9.9	-5.5	-5.4	3.3
10	-32.0	-21.7	-11.0	-7.8	-8.2	-4.2	-10.0	-5.3	-6.9	6.7
11	-23.0	-14.8	-13.8	-3.3	-11.7	0.7	-17.3	-1.7	-7.9	-1.7
12	-24.7	-14.8	-11.0	-0.4	-9.5	-2.1	-8.5	-2.6	-13.7	-0.7
13	-33.4	-24.6	-29.6	-10.8	-23.0	-4.0	-31.5	-4.5	-23.4	-5.6
14	-28.0	-8.4	-28.7	-9.8	-26.5	-9.6	-32.0	-17.5	-30.4	-15.1
15	-18.5	-7.7	-11.8	-5.7	-14.0	-0.4	-17.3	-2.5	-16.4	-0.9
16	-28.6	-18.3	-24.5	-11.2	-19.7	-6.2	-24.4	-7.4	-21.4	-6.5
17	-32.0	-17.9	-27.3	-20.0	-22.5	-16.2	-29.2	-16.8	-29.6	-16.1
18	-29.3	-16.7	-25.5	-12.5	-18.9	-10.1	-24.9	-11.1	-28.4	-9.6
19	-33.3	-20.5	-22.9	-15.4	-24.5	-14.2	-20.4	-16.9	-29.4	-15.9
20	-24.4	-16.1	-16.8	-2.6	-17.3	-1.0	-20.0	-5.1	-15.8	-3.4
21	-27.7	-18.3	-14.6	-6.8	-15.5	1.1	-15.9	-8.5	-5.4	-0.4
22	-24.3	-12.2	-12.2	2.4	-6.2	5.3	-16.1	-0.4	-3.2	5.3
23	-18.2	0.8	-5.5	6.3	-2.1	7.0	-12.0	6.1	0.8	5.4
24	-26.3	-18.2	-10.9	0.4	-7.2	5.3	-8.7	-1.3	-1.3	8.4
25	-28.3	-18.4	-17.9	2.3	-7.4	6.6	-13.5	1.8	2.4	9.3
26	-33.4	-17.1	-26.0	-1.9	-12.6	6.5	-20.8	-0.9	-9.0	7.4
27	-17.1	3.1	-2.0	7.1	5.9	8.9	-1.1	7.1	5.2	11.5
28	-12.7	0.1	-1.3	5.0	-0.6	12.4	-1.3	7.4	0.3	12.8
29	-19.6	-3.4	-7.3	1.5	-7.0	1.3	-11.3	1.6	-3.7	2.6
30	-11.7	4.5	-5.1	3.5	-5.7	11.3	-13.3	2.4	-2.7	11.2
31	-5.2	7.4	-3.2	4.0	0.9	12.7	-10.2	3.9	2.3	13.4

DAILY TEMPERATURES (C°)

February - 1984

Day	FORT MCMURRAY		LEDUC		CALGARY		RED DEER		LETHBRIDGE	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1	-10.4	-4.6	-4.1	5.2	-2.3	6.7	-10	5	-3.3	6.5
2	-9.1	6.0	-5.3	6.0	-2.8	10.3	-11	5	-3.5	10.3
3	-21.4	1.2	-4.2	3.4	-4.3	3.6	-5	3	-4.4	5.3
4	-29.2	-16.6	-10.2	3.0	-7.0	8.2	-12	-1	-6.5	10.0
5	-17.7	4.6	-9.1	6.5	-0.3	17.4	-9	6	1.2	17.8
6	-16.0	-4.2	-8.0	2.0	-1.2	11.3	-12	5	2.7	12.7
7	-11.9	3.0	-6.1	3.2	-5.4	10.9	-13	4	-2.4	12.8
8	-10.4	2.7	-4.8	6.6	1.5	12.1	-7	6	1.2	11.3
9	-17.0	-10.4	-6.7	2.5	-1.5	10.2	-11	4	-0.9	13.4
10	-20.0	-12.2	-8.7	4.2	-4.5	7.4	-10	5	-1.2	7.4
11	-22.8	-8.8	-7.8	-0.9	-6.0	6.1	-14	2	-3.2	7.8
12	-10.7	-0.3	-11.5	1.6	-3.1	9.2	-12	5	1.4	10.4
13	-11.0	-2.1	-6.9	4.6	-8.0	8.1	-13	3	1.4	9.5
14	-12.1	-3.5	-7.0	4.2	-2.4	7.9	-12	4	0.1	8.3
15	-13.3	1.2	-15.0	-1.4	-7.8	4.3	-18	-1	-6.3	6.5
16	-10.0	-2.4	-9.0	2.4	-9.7	3.5	-15	1	-8.2	4.7
17	-13.0	5.1	-10.4	1.7	-10.3	4.4	-18	1	-11.2	6.4
18	-12.1	7.0	-15.1	4.3	-8.5	9.0	-21	1	-6.0	9.4
19	-4.2	7.2	-6.7	3.0	-6.1	12.2	-16	3	-1.6	11.7
20	-4.0	11.6	-1.7	6.4	-1.2	16.0	-6	7	3.0	11.2
21	-1.9	7.2	-4.4	6.3	-4.9	6.6	-7	4	0.4	8.7
22	-5.8	-0.4	-7.8	2.5	-4.2	2.5	-8	2	-2.8	5.3
23	-9.8	2.7	-7.5	4.2	-5.0	5.1	-10	4	-4.2	6.0
24	-8.9	3.8	-11.5	1.3	-11.3	1.9	-15	1	-7.4	5.5
25	-11.6	-1.0	-10.9	0.0	-10.2	-1.0	-11	-1	-4.8	2.4
26	-16.3	-5.3	-12.0	0.6	-8.5	-1.5	-10	-1	-7.7	-1.2
27	-19.5	-3.2	-12.2	-2.5	-7.6	0.4	-9	1	-7.7	4.0
28	-7.9	-1.6	-8.7	-2.5	-8.5	7.5	-9	3	-3.4	11.4
29	-7.6	-2.5	-4.8	4.7	-3.2	7.7	-4	6	-0.4	10.6
30										
31										

DAILY TEMPERATURES (C°)

March - 1984

Day	FORT MCMURRAY		LEDUC		CALGARY		RED DEER		LETHBRIDGE	
	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1	-5.5	-1.0	-3.9	0.3	-5.4	0.6	-1	-4	-7.5	7.1
2	-1.8	5.4	-4.0	2.5	-4.7	7.4	2	-4	-7.0	9.3
3	-11.6	4.1	-5.1	4.1	-7.0	4.5	3	-5	-4.4	3.1
4	-13.8	-3.8	-7.5	2.6	-9.0	4.6	-1	12	-6.5	5.2
5	-10.5	-3.2	-3.7	4.6	-3.4	6.7	6	-9	-3.8	6.4
6	-18.3	-5.4	-8.7	4.9	-6.1	8.8	5	-12	-5.8	10.1
7	-26.3	-8.3	-15.5	-3.5	-9.1	1.6	4	-13	-9.4	1.7
8	-21.7	-8.3	-12.9	-4.2	-7.1	0.0	-2	-6	-7.0	8.5
9	-23.6	1.7	-13.0	7.9	-8.8	8.2	6	-17	-7.9	11.6
10	-22.0	-12.1	-13.0	1.4	-12.2	0.8	2	-12	-8.8	0.3
11	-29.2	-5.9	-17.1	-10.8	-18.1	-7.0	-10	-15	-11.4	-3.0
12	-22.9	-11.3	-20.6	-8.7	-14.0	-9.8	-11	-16	-10.9	-6.8
13	-31.6	-16.3	-18.5	-9.6	-21.0	-11.3	-10	-17	-11.0	-9.5
14	-32.6	-15.0	-20.4	-11.0	-19.5	-12.0	-11	-24	-14.4	-9.5
15	-33.5	-7.6	-26.6	-12.4	-25.2	-10.0	-13	-29	-17.8	-6.1
16	-16.6	0.4	-16.4	-2.3	-13.4	6.0	-2	-13	-11.9	9.7
17	-14.4	0.1	-12.8	-4.4	-9.2	6.2	-2	-15	-4.8	9.8
18	-4.1	3.5	-12.8	6.0	-1.8	10.7	5	-14	1.1	9.5
19	-3.5	8.5	-4.2	7.3	-1.7	10.6	6	-7	0	13.0
20	-5.1	11.3	-4.3	6.8	-6.0	8.2	6	-8	5.4	10.6
21	-1.6	8.2	-0.4	4.4	-1.9	4.1	6	0	0.5	9.4
22	-1.6	4.9	-1.3	11.1	-0.3	11.9	10	0	2.4	13.4
23	-5.3	3.6	-0.4	12.5	0.6	14.1	13	1	2.2	12.5
24	-2.4	6.0	-1.7	9.5	0.1	8.7	8	-2	-0.6	8.3
25	-4.2	6.3	-4.8	8.5	-5.1	7.1	8	-4	-4.2	8.2
26	-0.8	7.8	-2.0	2.1	-2.0	4.8	4	-2	-4.2	6.5
27	-5.0	11.6	-5.0	9.8	-2.2	7.4	8	-1	-3.5	6.0
28	-1.7	12.3	-3.1	10.2	-5.5	8.8	9	-2	-5.9	6.0
29	-1.4	12.6	-2.6	11.3	-2.4	6.2	9	-2	-2.8	10.7
30	-3.3	15.1	-5.0	11.9	-5.6	7.6	9	-5	-5.6	8.4
31	-2.3	13.4	-4.4	10.4	-7.0	7.2	7	-4	-0.2	8.2

APPENDIX B

SURVEY ANALYSIS

Mobile Homeowners Response

Response to Questions 4, 5 and 6.

	Year Mobile Home Manufactured		Years Set On Foundations		Year Respondent Moved In	
	Number of Responses		Number of Responses		Number of Responses	
Prior to 1974	13	20 %	7	12 %	2	3 %
1974	5	8 %	4	7 %	3	4 %
1975	4	6 %	3	5 %	1	1 %
1976	6	9 %	2	3 %	5	7 %
1977	5	8 %	6	10 %	6	8 %
1978	6	9 %	5	8 %	3	4 %
1979	2	3 %	3	5 %	4	5 %
1980	2	3 %	2	3 %	7	9 %
1981	6	9 %	5	8 %	9	12 %
1982	4	6 %	6	10 %	9	12 %
1983	8	12 %	5	8 %	13	17 %
1984	5	7 %	9	15 %	13	17 %

Response to Question 7 - How long have you lived in a manufactured home?

		Responses	
12 Months or less	-	13	16 %
1 year to 2 years	-	12	15 %
2 to 3 years	-	7	8 %
More than 3 years	-	46	58 %

Response to Question 8 - Summary of unit sizes

		Responses	
12 foot wides	-	12	15 %
14 foot wides	-	49	62 %
16 foot wides	-	9	11 %

Double Wides

20 foot wides	-	1	1 %
22 foot wides	-	1	1 %
23 foot wides	-	1	1 %
24 foot wides	-	4	5 %
28 foot wides	-	1	1 %

Response to Question 9 - Does Unit have attached Structure

		Responses	
Attached structure	-	49	62 %
Does not have	-	29	37 %

Questions 10 & 11 - Number & types of Foundation Support

Type of Support	Average Number Used Unit	Total Number of Units Using Foundation Type	% of Respondents
Concrete Pile	16	6	8 %
Wood Pile	14	11	14 %
Concrete Block	NK	3	4 %
Wood Blocks	16	58	73 %
Masonry	NK	1	1 %

Question 12 - Orientation of Unit at Site

Responses			
North	-	18	27 %
North West	-	3	4 %
West	-	16	24 %
South West	-	4	6 %
South	-	8	12 %
South East	-	1	1 %
East	-	12	18 %
North East	-	5	7 %

Question 13 - Prevailing Wind Direction?

	Responses	
North	5	7 %
North West	32	44 %
West	24	33 %
South West	5	7 %
South	0	0 %
South East	2	3 %
East	1	1 %
North East	3	4 %

Question 14A - Naturally Protected from wind?

Yes	17	23 %
No	56	77 %

Question 14B - Protected by Neighbour s Unit?

Yes	49	74 %
No	17	25 %

Question 15 - Does Unit Rock in the Wind?

Yes - Gently	20	30 %
- Roughly	0	0 %
- Violently	0	0 %
No	46	70 %

Question 16 - Has Your Unit Experienced Any Wind Damage?

Yes	-	4	8 %
No	-	47	92 %

Question 17 - Has Unit Moved Because of Wind?

Yes	-	1	1 %
No	-	75	99 %

Question 18 - Height of Main Floor Above Grade?

Responses

1" - 16"	-	1	1 %
16" - 24"	-	14	18 %
24" - 32"	-	25	33 %
32" - 40"	-	28	37 %
Above 40"	-	8	11 %

Question 19 & 20 - Is Unit Skirted?

- Yes 78 - 100%
- No 0 - 0%

Is Skirt Tight to Ground?

Yes	61 -	79 %
No	16 -	21 %

Is Skirt Insulated?

Yes	15	21 %
No	58	79 %

Question 21	- Door Jamming?		
Yes	-	28	36 %
No	-	49	64 %
Question 22	- Window Jamming?		
Yes	-	5	7 %
No	-	71	93 %
Question 23	- Was Floor Level When Moved In?		
Yes	-	58	83 %
No	-	12	17 %
Question 24	- Is Your Floor Level Now?		
Yes	-	58	75 %
No	-	19	25 %

If "NO" by how much does it slope in 10 feet?

				Angular Distortion
Level				0
Less than	1/4"	-	2	1:480
	1/4"	-	1	1:480
	1/2"	-	5	1:240
	3/4"	-	2	1:160
	1 "	-	1	1:120
	1 1/4"	-	1	1:96
	1 1/2"	-	0	1:80
Greater than	1 1/2"	-	0	0

Are You Upset with the slope?

Yes	-	1	5%
No	-	18	95%

Question 25 - Do You Level Your Own Home?

Yes	-	33	47%
No	-	38	53%

If "Yes" how do you do this?

- By Jacking the unit and using Wood Wedge?

Yes	-	25	36%
No	-	0	0%

- By Hiring someone?

Yes	-	8	11%
No	-	0	0%

- Does Mobile Park Owner level?

Yes	-	3	4%
No	-	35	49%

Question 27 - At What Temperature is Your Thermostat Set In Winter?

- Night 21 degrees centigrade.
- Day 22 degrees centigrade.

Building Inspector Response

Total Number of Responses	75
Total Number Non-Involved	39
Total Number of Meaningful Responses	36

Question 3 - Total Number of Complaints per Year?

0	24	67 %
1 - 5	11	31 %
10 - 20	1	3 %

Note: 10 - 20 Most Units Placed in Black Soil.

Question 4 - Complaints From One Park:

Yes	-	4	33 %
No	-	8	68 %

Question 5 - Type of Foundation

	Most Troublesome:		Least Troublesome?	
Concrete Pile	- 1	2 %	12 -	21 %
Wood Pile	- 4	7 %	4 -	7 %
Concrete Block	- 4	7 %	4 -	7 %
Wood Block	- 8	14 %	14 -	24 %
Masonry	- 4	7 %	2 -	3 %

Question 6

Any Sliding on Wood Block Foundation?

Yes	5	15 %
No	27	79 %
Not Known	2	5 %

Any Other Foundation Type?

Yes	0	0 %
No	21	58 %
Not Known	15	42 %

What Was Cause of Sliding?

Wind	3	9 %
Settlement	4	11 %
Poorly Constructed	1	3 %
Poor Anchorage	3	9 %
Not Known	24	69 %

Question 7 -

In What Town is the Park With Most Complaints Located?

Question 8 -

Park with Highwater Level?

	Yes	No	Not Known
Hanna	1		
Fort McMurray	1		
Fort MacLeod		1	
Pincher Creek	1		
Edson	1		
Calgary		1	

Valleyview	1		
Strathmore		1	
Wetaskiwin	1		
Vulcan			1
	None	25	69 %
		36	100 %

Question 9 -

What native soil type is the park located with the most complaints?

Gravel	1	8 %
Clay	3	25 %
Sandy-clay	3	25 %
Silty-clay	3	25 %
Sand	0	0 %
Other fill Material	1	8 %
Not known	1	8 %

Questions 10 & 11 -Number & types of Foundation Support

Type of Support	Average Number Used Unit	Total Number of Units Using Foundation Type	% of Respondents
Concrete Pile	16	6	8 %
Wood Pile	14	11	14 %
Concrete Block	NK	3	4 %

Wood Blocks	16	58	73 %
Masonry	NK	1	1 %
Other	0	0	0 %

Question 12 - Orientation of Unit at Site.
Responses (Long Side Facing)

North	-	18	27 %
North West	-	3	4 %
West	-	16	24 %
South West	-	4	5 %
South	-	8	11 %
South East	-	1	1 %
East	-	12	17 %
North East	-	5	7 %

Question 10 -

Was Base Prepared?

Yes	14	41.18%
No	10	29.41%
Not Known	10	29.41%

Type of Base Used?

Fill Material	2	6 %
Asphalt	1	3 %
Concrete	2	6 %
Gravel	7	19 %
Other	0	0 %
Not Known	24	67 %

Question 11 - Was Base Fully Compacted?

Yes	6	17 %
No	6	17 %
Not Known	24	67 %

Question 12 - Was Native Soil Prepared?

Yes	10	28 %
No	5	14 %
Not Known	21	58 %

Question 13 - Was Prepared Base Stable and Adequate?

Yes	14	38 %
No	2	5 %
Not Known	20	55 %

Question 14 - Is Wood Block Suitable For Your Area?

Yes	20	55 %
No	6	16 %
Not Known	10	27 %

Question 16 - What Type of Foundation is Suitable?

Concrete Pile	8	22 %
Wood Pile	3	8 %
Concrete Block	2	6 %
Wood Block	10	28 %
Masonry	0	0 %
Not Known	13	36 %

Park Managers Response

Question 3 - What Foundation Type is Most Used?

Concrete Pile	4	7 %
Wood Pile	3	5 %
Wood Block	43	77 %
Concrete Block	2	4 %
Masonry	2	4 %
Other	2	4 %

Question 4 -

Selection of Foundation by Buyer?		What Type?	
Yes	20	Manufactured	3
No	25	Park Designer	0
		Park Owner	15
		Dealer	25
		Door Jamming	2
		Other	2

Question 6 - Average Weight of Unit?

Responses Did Not Differentiate Manufacturer With Weight

For Unit Size 4.3m x 21.3m (14 ft. x 70 ft.)
Average Wt - 11,400kg. (25,000 lbs.)

For Unit Size 5.0m x 21.3m (16 ft. x 75 ft.)
Average Wt - 15,000kg. (33,000 lbs.)

Question 7 - Do You Level For The Purchaser?

Yes	25
No	22

How Often? Generally Once With 6 Month Follow-Up

If No - Who Levels?

Manufacturer	1
Purchaser	13
Supplier	1
Dealer	4
Mover	3

Question 8 - How Do You Determine Levelness?

Transit	4
Level Instrument	5
Carpenters Level	27
Surveyor	1
Other Means	1

Question 9 - How Do You Level the Unit?

Adjustable Bolts	1
Not Adjustable	1
Shims	41
Other	1

Question 10 - The Type of Foundation Preferred

Concrete Pile	8	16 %
Wood Pile	2	4 %
Wood Block	31	61 %
Concrete Block	4	8 %
Masonry	1	2 %
Other	5	10 %

Question 11 - Any Ground Water Problems?

Yes	13	26%
No	37	74%

Question 12 - Are Foundations Affected by Ground Water?

Yes	11	24 %
No	35	76 %

Question 13 - Are There Strong Winds in Your Area?
If So, How Strong?

Yes	28	65 %	30 kmph	6	11 %
			40 kmph	4	8 %
No	15	35 %	50 kmph	12	23 %
			60 kmph	11	19 %
			100 kmph	10	19 %

Question 14 - Specific Cases of Damage Due To Foundation Failure?

Yes	6	12 %
No	44	88 %